Kohima water supply: Assessment and Strategies

Phase 2 submitted to

Visvesvaraya National Institute of Technology,

Nagpur in partial fulfillment of the

requirements for the award of the degree

Master of Technology

in

Urban Planning

by

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2024-25

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I, **Suduvo Chizo**, hereby declare that this project titled **"Kohima water supply: Assessment and Strategies"** is carried out by me in the **Department of Architecture and Planning** of Visvesvaraya National Institute of Technology, Nagpur. The work is original and has not been submitted earlier whole or in part for the award of any degree/diploma at this or any other Institution/University.

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Acknowledgement

Foremost, I would like to express my sincere gratitude to my project guide Dr. V.S Adane for his constant help, patience, motivation and guidance. He has been helping me out and supported throughout the course of work and several other occasions with her attention, cooperation, comments and constructive criticism.

I express my deep gratitude to Dr. Sameer Deshkar, Head of the Department, Department of Architecture and Planning, and **Prof. (Dr.) Prem Lal Patel**, Director, Visvesvaraya National Institute of Technology, Nagpur, for providing all the necessary facilities to carry out study for project phase 2.

On a concluding note, I am thankful to my parents and for their moral as well as financial support.

-Suduvo Chizo

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Abstract

This study assesses the water supply problem of Kohima, the Nagaland state capital, and suggests sustainable policy and infrastructure interventions to alleviate these problems. Kohima's municipal presently faces a severe shortage of water: with a treated supply of around 5.9 MLD against demand of 13.3 MLD, creating a deficit of over 55%.

This shortage is further worsened by spatial disparities, with higher-elevation and outer wards bearing a unbalanced burden due to the practice of nearness-based distribution. Population growth is expected to grow swiftly, rising from ~99,000 in 2011 to over 258,000 by 2041 and push daily demand close to 35 MLD, increasing gap challenges unless forestalled through proactive planning.

GIS analysis shows Kohima's rooftop RWH potential at around 4,121 million Liters (ML) per year, which is equivalent to a daily average of ~35.5 MLD—far more than the city's existing demand of ~18 MLD

Household survey indicate that 85% of the households get piped water for less than one hour during supply event, almost half get water only twice a week, and 72.8% find volumes insufficient—compelling more than 77% to use private tankers for as long as six months a year. According to these results, an integrated intervention plan is hereby recommended: upgrading and optimizing distribution systems; increasing service reservoirs (to address an estimated 17.42 MLD storage need by 2041); adopting ward-level RWH mandates and tanks at the community scale; and applying smart metering and SCADA systems to minimize non-revenue water (presently ~30%) and facilitate real-time monitoring

For proposals, Policy suggestions involve amending building regulations to mandate RWH infrastructure for new/redeveloped buildings, providing incentives, and allocating some percentage of PHED's urban water budget to maintenance and leak control. Taken together, these policies will help close the demand–supply gap, increase equity, and build resilience to seasonal scarcity, ensuring sustainable urban water security for Kohima.

Keywords: Kohima, water supply, demand–supply gap, rainwater harvesting, GIS mapping, household survey, water quality.

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CHAPTER 1 - INTRODUCTION

1.1 Background

Water is a fundamental resource that sustains life, ecosystems, and economic development. Despite its critical importance, water is unevenly distributed across the globe, leading to challenges in ensuring equitable and sustainable access. Over the past century, global freshwater use has increased exponentially, from approximately 500 billion cubic meters in 1900 to over 3,900 billion cubic meters in recent years(Our World in Data). Agriculture

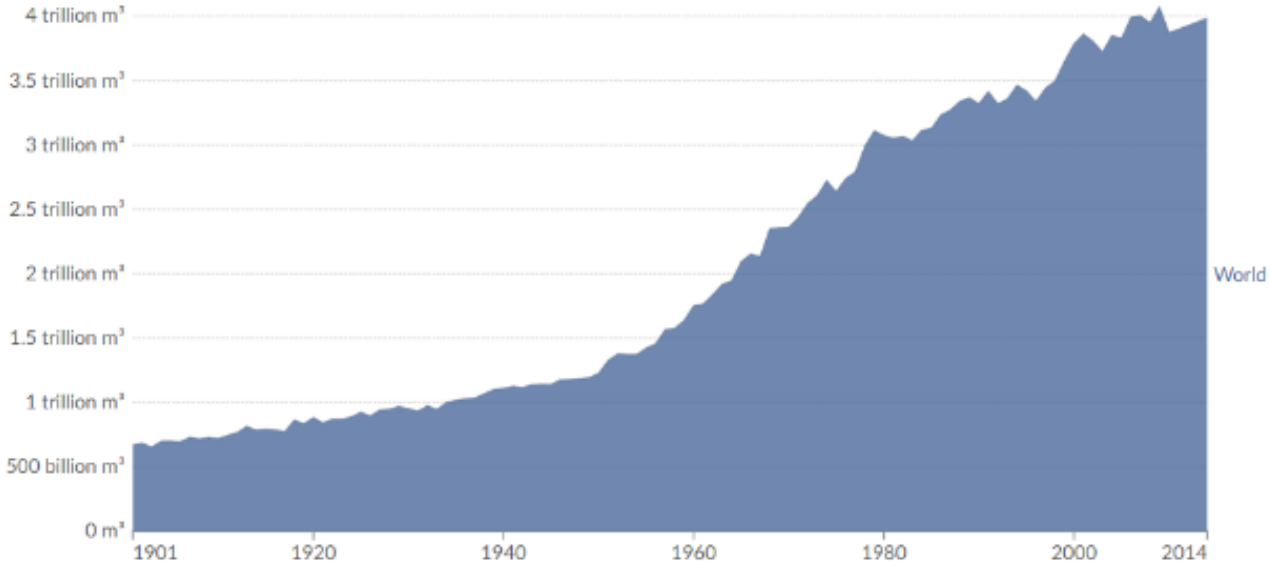
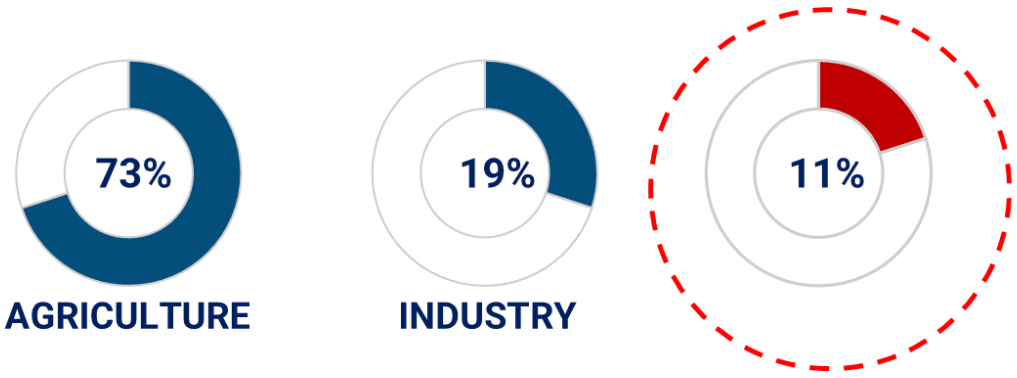


Figure 1:Graph showing withdrawals of water over the years.

dominates global water usage, followed by industrial and domestic needs, highlighting the interconnected pressures on this vital resource.



In India, the challenges of water management are particularly pronounced due to its large population and limited freshwater availability. With 17.74% of the global population, India holds only 4.5% of the world's freshwater resources (Ministry of Water Resources,

December 2008). Rapid urbanization, population growth, and industrialization further strain water resources, making sustainable management a national priority.

Hill cities in India, especially those in the Himalayan region, face unique obstacles in water supply and distribution. The steep and fragile terrain complicates infrastructure development and maintenance. Seasonal variability in rainfall exacerbates the challenges, leading to periods of water scarcity. Many of these cities depend on outdated pipelines, suffer from high non-revenue water (NRW), and lack adequate metering and treatment facilities. Additionally, the increasing demand from growing populations and tourism amplifies these pressures, putting immense strain on limited water resources.(n.d.)

The geographical and socio-economic conditions of hill cities demand tailored approaches to water management. This includes leveraging modern tools like GIS mapping and hydraulic modelling for efficient water distribution, as well as integrating surface water, groundwater, and rainwater harvesting systems to diversify water sources(WI.Plat, n.d.). These strategies are essential to address the inequities, inefficiencies, and vulnerabilities in existing water supply systems and to build resilient frameworks for the future.

1.2 Need for the Study

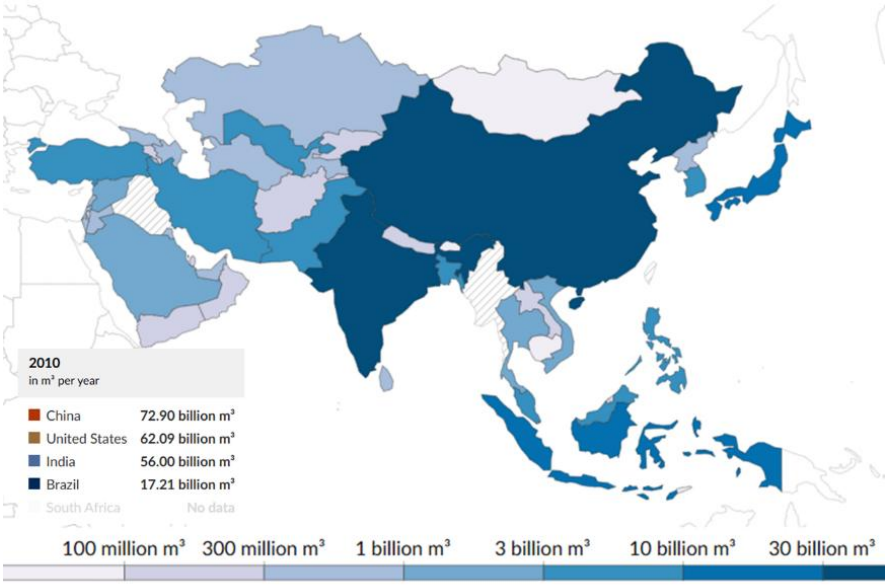


Figure 2: Total water withdrawal for municipal (domestic) purposes

India's urban water supply systems face significant problems driven by increasing population increase, urbanization, industrial expansion, and climate unpredictability. In

2010, India pulled nearly 56 billion cubic meters of water for municipal use(Ritchie & Roser, 2018), demonstrating the huge pressure on resources to meet urban demands. This is anticipated to expand substantially, with urban India's municipal water consumption rising from 50 billion liters per day in 2021 to 110 billion liters per day by 2050(CPCB, n.d.). Such increased demand underlines the need for strategic water conservation, infrastructure investment, and sustainable water management strategies.

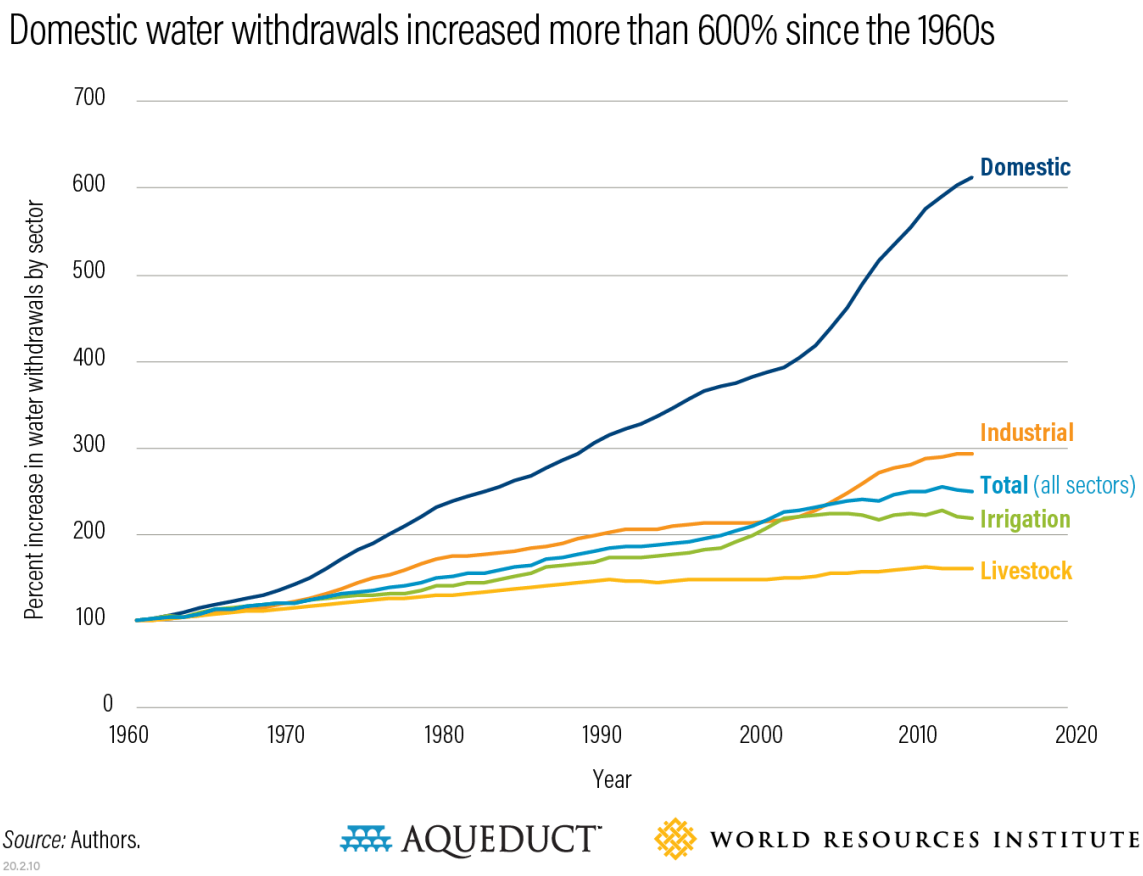


Figure 3:Statistics showing the percent increase in water consumption by various sectors

Hilly regions, like those in the Himalayan nations, confront additional obstacles due to their complicated geology, steep terrain, and fragile ecosystems, which make infrastructure construction and maintenance challenging. These locations generally suffer from uneven water supplies, seasonal scarcity, and high amounts of non-revenue water (NRW)(Bahadur, 1998). Existing systems are further challenged by increased tourism, urban development, and inadequate water treatment and distribution capacity. Additionally, household water consumption has grown by 600% globally between 1960 and 2014(WRI, 2020), stressing the necessity for novel techniques to divorce water use from socioeconomic development.

To overcome these difficulties, there is an urgent need to:

- Improve distribution networks to eliminate losses and provide equal access.
- Explore alternative water sources, including rainwater gathering and wastewater recycling.
- Encouraging water conservation through awareness and community involvement.
- Implementing integrated water management systems to diversify water sources.
- Adapting to climate change impacts to ensure future water supplies.

1.3 Challenges in Water Supply Systems in Hill Cities

1. Steep Terrain: Rugged and uneven landscapes affect the installation and maintenance of water distribution networks. This increases expenses and necessitates complex engineering solutions, where steep topography provides substantial obstacles(S. Sharma et al., 2019).

2. Natural Disasters: Frequent landslides and earthquakes in hill cities damage pipelines and reservoirs, leading to disruptions in water delivery. (GEOHAZARDS INTERNATIONAL, 2021)

3. Water Source Scarcity: Over-reliance on natural springs, which are subject to drying up due to deforestation and climate change, leads in water shortages. Many hill cities suffer this dilemma, with dwindling resources unable to fulfil expanding needs.

4. High Elevation Challenges: Pumping water to elevated places needs tremendous energy and infrastructure, making it both costly and difficult to maintain. Cities like Aizawl and Shimla experience substantial obstacles due to their high-altitude positions.

5. Pressure Problems: Maintaining enough water pressure in pipelines is challenging in hill cities due to uneven elevation. places at higher altitudes often confront low pressure, leading to insufficient supplies, while lower places may experience overpressure, causing pipe bursts and leaks.

6. Low Temperature Issues: In colder hill cities, freezing temperatures can cause

pipelines to freeze, resulting to obstructions and problems in the water distribution system. Insulating pipelines and constructing freeze-resistant infrastructure are important to address this hazard.

7. Siltation: Erosion and landslides result in silt buildup in water bodies, limiting water availability and quality. Managing siltation needs regular dredging, which raises operational costs.

8. Limited Storage: Seasonal water supplies and poor storage facilities worsen water shortages during dry years. Additional storage tanks and reservoirs are needed for improving supply reliability.

9. Unplanned Urbanization: Rapid and unregulated urban growth strains existing water resources and infrastructure. This leads to inadequate supply and increased competition for limited resources. Sustainable urban planning is crucial to solve this issue successfully.

10. Inefficiencies and Losses: High levels of Non-Revenue Water (NRW) due to leaks, illegal connections, and old infrastructure further strain the system, lowering the availability of water for legitimate use.

Hill cities require specific solutions to handle these multiple issues, providing sustainable and efficient water delivery systems.

1.4 Overview Of Water Supply in India

In India, urban water supply is regulated by local government organisations and utilities, but the infrastructure and effectiveness of these systems vary greatly across cities. Rapid urbanization and population increase have placed great pressure on the country's water supplies. The urban population is predicted to rise from 31% to roughly 40% by 2030(Aayog, 2019), which would further strain water supply systems, worsening shortages and inefficiency in many places.

Currently, 600 million Indians endure high-to-extreme water stress, according to the CWMI Report 2018 by NITI Aayog. Additionally, 97 million Indians lack access to safe water, the second-highest figure behind China (WHO). This challenge is aggravated by

uncontrolled urbanization, which has resulted in chaotic city expansion, altering local ecology, hydrology, and the environment. Unplanned growth has led to insufficient infrastructure, excessive demand, and considerable inefficiencies in water distribution(NITI AAYOG, 2023).

India's per capita water storage capacity is only 209 m^3, which is much lower compared to countries like Australia, which has a capacity of 3,223 m^3 (Aayog, 2019). This inadequate storage capacity, coupled with a severe imbalance between water resources and population, exacerbates water scarcity. India houses 18% of the worldwide population yet has access to only 4% of the world's water resources, leading to regional disparities in water availability

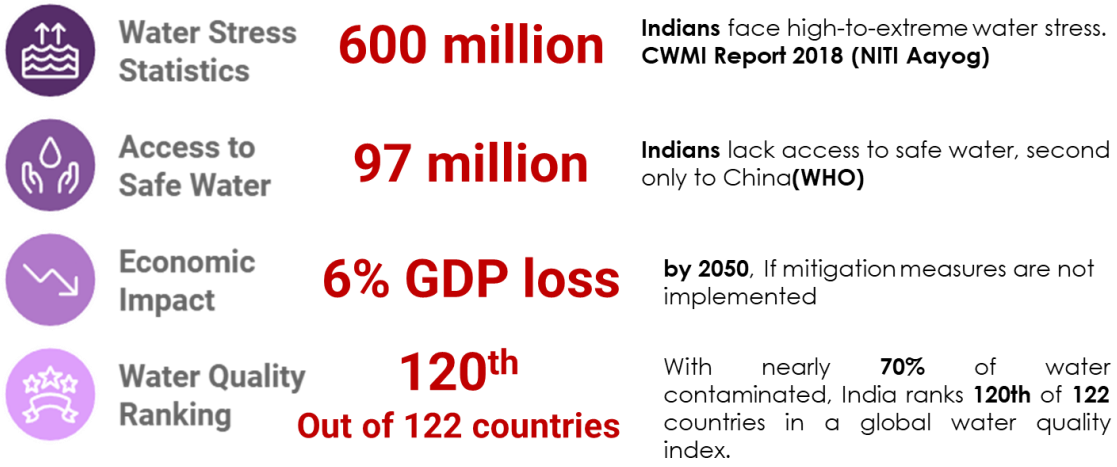

Water Stress Statistics
600 million
Indians face high-to-extreme water stress.
CWMI Report 2018 (NITI Aayog)
Access to Safe Water
97 million
Indians lack access to safe water, second only to China(WHO)
Economic Impact
6% GDP loss
by 2050, If mitigation measures are not implemented
Water Quality Ranking
120th
Out of 122 countries
With nearly 70% of water contaminated, India ranks 120th of 122 countries in a global water quality index.

Figure 4: STATUS OF WATER CRISIS IN INDIAN CITIES

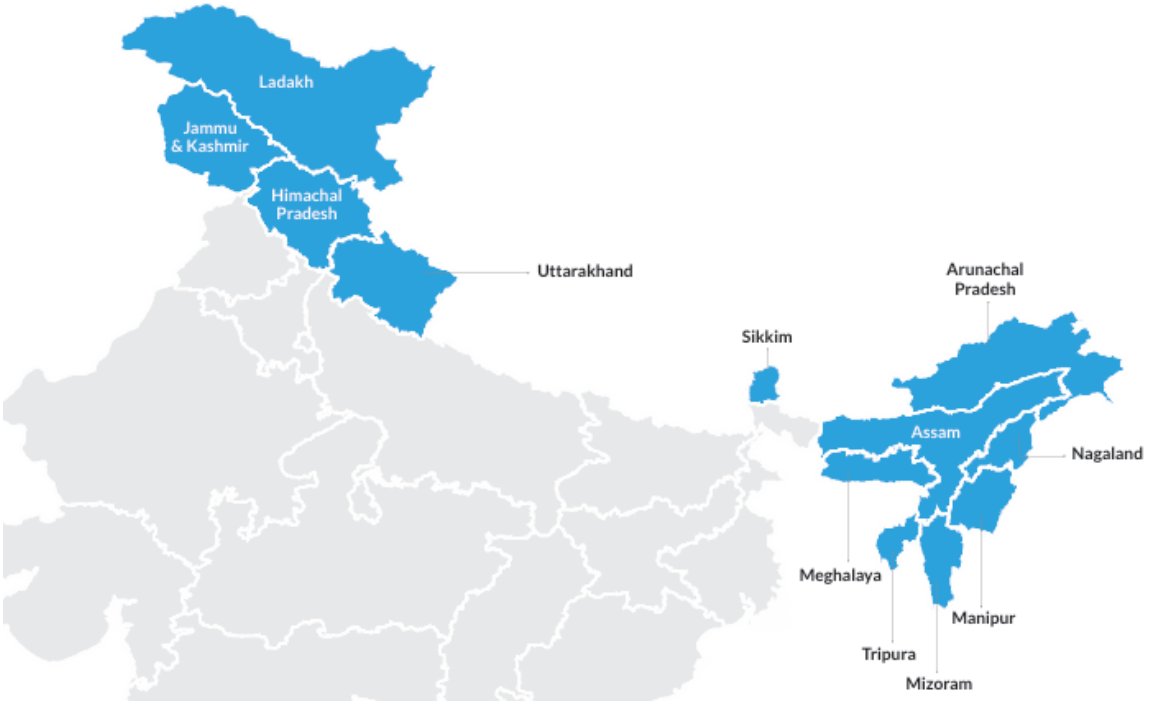
Further underscoring the seriousness of the problem, if mitigating measures are not adopted, India might experience a 6% GDP loss by 2050. Additionally, nearly 70% of the country's water is contaminated, and India ranks 120th out of 122 countries in a global water quality index.

Reasons Behind the Water Crisis in India:

- **Unplanned Urbanization:** Rapid, unrestrained urban expansion affects local ecosystems and places pressure on water systems.
- **Poor Storage Capacity:** The country's inadequate per capita storage capacity is insufficient to accommodate escalating demand.
- **Uneven Water Resource Distribution:** Despite a massive population, India has restricted access to global water resources.

- **Contamination:** A major amount of India's water supply is contaminated, rendering it unsuitable for consumption.
- **Climate Change:** Fluctuating rainfall patterns and extreme weather events add to the uncertainty and variability of water supplies.

1.5 Scenario in Indian Himalayan States



The water supply and distribution systems in Indian Himalayan hill region face unique problems generated by a mix of topographical, infrastructural, and population considerations (Kumar Padhi et al., 2023)

Geographical Complexity:

- The Indian Himalayan Region (IHR) spans roughly 4.3 lakh sq km across 12 states, including important states like Arunachal Pradesh (83,743 sq km) and Assam (78,438 sq km).
- The region contains great fluctuations in elevation, from Jammu and Kashmir's average of 2,717 m above MSL to Tripura's 65 m above MSL, hindering water retention and infrastructure development.

Demographic Pressures:

- The region accommodates a population of 73 million, with Assam (3.12 crore) being the most populous state, followed by Jammu & Kashmir (1.22 crore).
- Urban regions account for roughly 30% of the population, close to the national

average, but states like Mizoram have a substantially larger urban population (52.11%).

- Population densities are generally lower than the national average of 382 inhabitants per sq km, except Assam (398 persons per sq km).

Water Supply Infrastructure:

- Access to piped water supply averages 68% across the IHR, with Uttarakhand having the highest rate (85%). However, old municipal systems and deteriorating infrastructure result in leaking pipes, uneven supply, and limited storage capacity.
- States like Assam, Mizoram, Nagaland, and Meghalaya rely heavily on groundwater, whereas Manipur leads in accessing surface water sources (27%).

Natural and Seasonal Challenges:

- The steep slopes and quick surface runoff restrict water retention and aquifer recharging.
- Seasonal unpredictability, especially reliance on monsoon rains, resulting in water shortages during dry months.
- Slope instability and landslides increasingly impair water infrastructure.

Urban Growth and Tourism:

- Urbanization and a developing tourism economy create extra demands on already stressed water supply infrastructure, aggravating disparities in distribution.

Population Growth Variability:

- Meghalaya has the highest population growth rate (27.90%), followed by Arunachal Pradesh (26%), indicating future stresses on water resources in these states.

CHAPTER 2 - SYNOPSIS

2.1 AIM

To assess the water supply challenges in Kohima and give sustainable solutions

2.2 OBJECTIVE:

1. To analyze the existing water supply scenario in Kohima.
2. To evaluate the demand-supply gap
3. To identify the challenges in the existing water supply system.
4. Estimate rooftop rainwater harvesting (RWH) potential using GIS.
5. Incorporate household survey findings to understand access, adequacy, and coping strategies.
6. Propose infrastructure and policy recommendations including supply augmentation, RWH, smart metering, and SCADA systems.

2.3 SCOPE:

1. The study focuses on Kohima Municipal area.
2. The study will examine the existing water supply infrastructure
3. The study will analyze the current and projected water demand in Kohima, considering population growth and urbanization trends.
4. GIS-based spatial mapping of RWH potential across different wards based on the parameters.
5. Provides policy and infrastructure recommendations for sustainable water management.

2.4 LIMITATIONS:

3 The study is limited to the Kohima Municipal Area

4 The study may not fully capture the operational challenges of the existing water supply infrastructure, such as maintenance issues and pipeline leakages, due to limited access to real-time data.

5 Data accuracy depends on the resolution of building footprint and roof material datasets.

6 Seasonal rainfall variations may impact RWH efficiency.

7 Implementation depends on public awareness and municipal policies.

2.5 METHODOLOGY

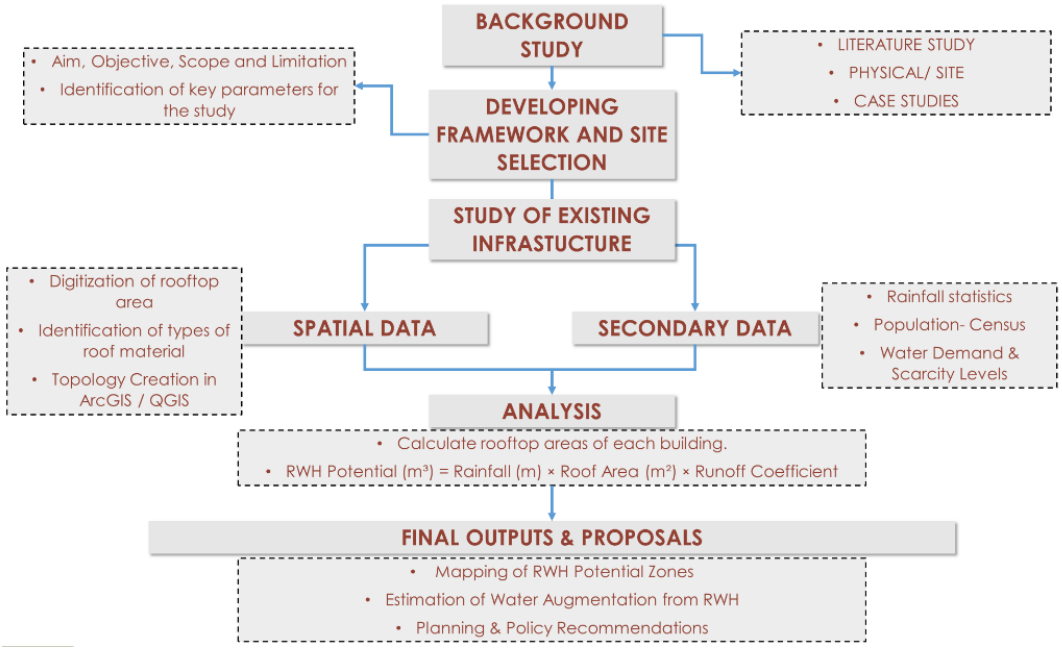

BACKGROUND STUDY
• LITERATURE STUDY
• PHYSICAL/ SITE
• CASE STUDIES
• Aim, Objective, Scope and Limitation
• Identification of key parameters for the study
DEVELOPING FRAMEWORK AND SITE SELECTION
STUDY OF EXISTING INFRASTUCTURE
• Digitization of rooftop area
• Identification of types of roof material
• Topology Creation in ArcGIS / QGIS
SPATIAL DATA
SECONDARY DATA
• Rainfall statistics
• Population- Census
• Water Demand & Scarcity Levels
ANALYSIS
• Calculate rooftop areas of each building.
• RWH Potential (m³) = Rainfall (m) × Roof Area (m²) × Runoff Coefficient
FINAL OUTPUTS & PROPOSALS
• Mapping of RWH Potential Zones
• Estimation of Water Augmentation from RWH
• Planning & Policy Recommendations

Figure 5: Methodology

CHAPTER 3 - LITERATURE REVIEW

3.1 PAPER REVIEWS

Table 1: Paper reviews

TITLE	YEAR	AUTHOR(S)	FOCUS	METHODS USED
Geospatial Modeling of Dehradun's Water Supply(Jaiswal et al., 2021)	2021	A. K. Jaiswal, P. K. Thakur, P. Kumar, S. Kannaujiya	GIS/EPANET analysis of pipeline defects and pressure zones	GIS mapping (564 km network); EPANET simulations
Resource Assessment for Shimla Using GIS & SWAT(S. K. Sharma et al., 2015)	2015	Sham Kumar Sharma, M.L Kansal, Aditya Tyagi	GIS-based evaluation of Shimla's water deficit and RWH sites	SWAT hydrological modeling; GIS spatial analysis
GIS-Based RWH Site Suitability in Gilgit Basin(Asif et al., 2024)	2024	Madiha Asif, Muhammad Yaseen, Syed Umair Shahid, Yasir Latif	Identifying rainwater-harvest sites in high-altitude terrain	GIS multi-criteria evaluation; remote sensing
Rainwater Harvesting Potential in Nagaland(Lalmalsawmzauva et al., 2021)	2021	K.C. Lalmalsawmzauva Uday Chatterjee	Quantifying rooftop RWH versus demand across Nagaland towns	Google Earth rooftop digitization; runoff modeling
Water Distribution Modeling (Bota Town,	2024	Pranit Dongare, V.	Hydraulic modeling to	GIS network layers;

MP)(Dongare et al., 2024)		Sharma, V. Kumar, A. Mathew	locate leaks and head-loss zones	EPANET hydraulic simulations
Smart Metering & SCADA for NRW Reduction (Bangalore case)(Mukherjee et al., 2015)	2013	Maitreyee Mukherjee, Namrata Chindarkar et al.	Impact of smart metering and SCADA on reducing NRW	NRW water balance; stakeholder interviews; meter pilots

Many recent studies offer insightful methodological and contextual analysis that helps one better grasp urban water supply issues in hill cities such as Kohima. The GIS and EPANET-based study of Dehradun's water network by (Jaiswal et al., 2021) revealed that over 50% of zones suffered negative pressure and 27% of pipelines were undersized, therefore highlighting the need of spatial diagnostics for the improvement of infrastructure. In Shimla,(S. K. Sharma et al., 2015) used GIS tools and hydrological modelling (SWAT) to project a 42 MLD shortage by 2031 and suggested scattered rainwater collecting (RWH) and service reservoirs as workable remedies. Using multi-criteria GIS analysis, (Asif et al., 2024) assessed RWH suitability in Gilgit and discovered that steep slopes and land usage limited potential RWH sites to just 4%—a constraint equally pertinent to the topography of Kohima. While small towns may fulfil up to 24% of demand, Kohima's bigger population and demand meant RWH alone would be insufficient, according to (Lalmalsawmzauva et al., 2021), who evaluated Nagaland's district-wise rooftop RWH capacity. Lessons directly relevant to Kohima's mountainous topography, (Dongare et al., 2024) mapped hydraulic head losses using GIS and EPANET modelling in Bota Town and offered booster pumps and SCADA systems to maximise performance. Ultimately, (Mukherjee et al., 2015) looked at smart metering and SCADA deployment in Bangalore, demonstrating how these technologies lowered non-revenue water and enhanced system transparency, therefore supporting their relevance for Kohima's proposed smart water governance initiatives.

3.2 Types of water distribution system

Water distribution systems play a vital role in ensuring the consistent and efficient delivery

of water to consumers. The design and type of system used depend on the geographical, technical, and economic conditions of the region. Broadly, there are three main types of water distribution systems: gravity, pumping, and combined systems.

Gravity system: It relies exclusively on gravity force to convey water from high-level sources to low-level consuming zones. This technique is particularly useful in places with substantial elevation changes, such as hill cities, as it removes the need for pumping. Service reservoirs in higher regions maintain steady pressure at consumer taps, decreasing water loss and leaks. The gravity system is cost-effective, reliable, and requires low maintenance as it does not contain mechanical components like pumps. However, its efficacy is dependent on the elevation difference; locations without sufficient head difference cannot employ this system successfully as it fails to generate significant pressure.

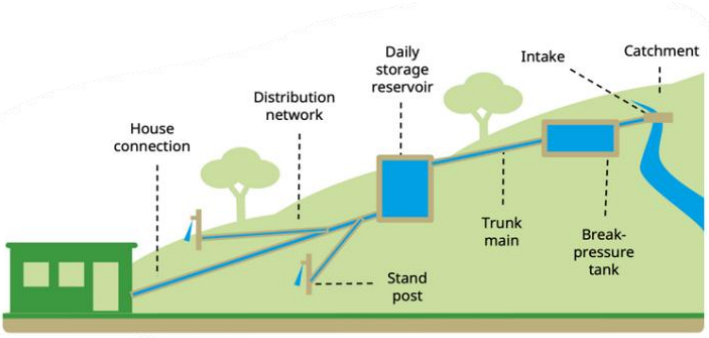


Figure 6: Gravity System

Pumping system:

Pumping system on the contrary, depends on high-lift pumps to deliver water straight to distribution mains, eliminating storage reservoirs. This technique is suitable for flat locations where gravity flow cannot be exploited. That stated, its reliance on consistent power supply and pump efficiency exposes it to interruptions. To address this, backup pumps powered by diesel are routinely employed. The pumping system needs to be kept under continual check to control water supply, altering pump speed based on necessity. Although successful in

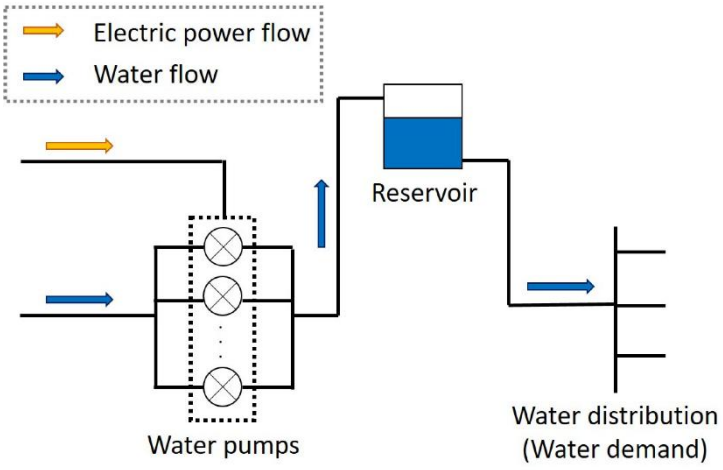


Figure 7:Pumping system

specialised applications, it is not economical due to its pricey maintenance and initial installations and required expert monitoring.

Combined system:

It offers a balanced approach by integrating components of both gravity and pumping systems. Water is pumped into elevated service reservoirs (ESRs) and then delivered to users by gravity as needed. This system assures continuity of supply even during power or pump failures, making it highly reliable. Pumps in the combined system run at a constant rate, optimizing efficiency and decreasing operational costs compared to a solo pumping system. It also eliminates the need for expert supervision, making it appropriate for places that require a mix of mechanical and gravitational forces for water distribution. Each system type is geared to solve distinct obstacles, with the gravity system recommended in steep terrains, the pumping system in flat areas, and the combined system in locations requiring a hybrid approach. These systems constitute the backbone of water distribution networks, ensuring water reaches users reliably and responsibly.

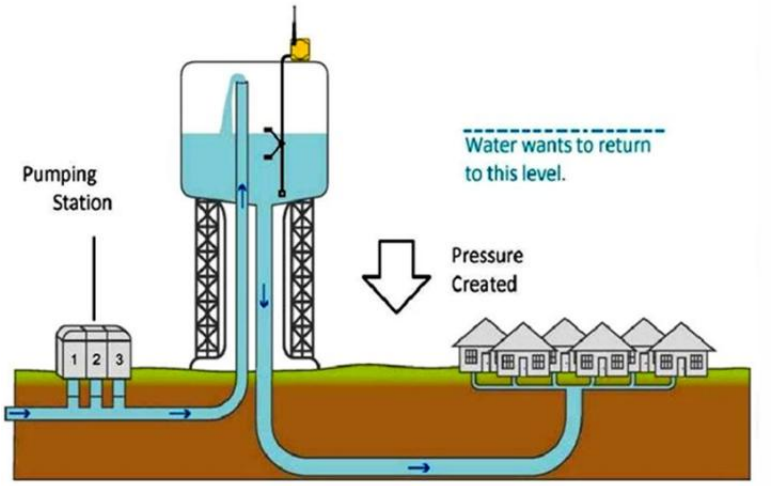


Figure 8:Combined system

3.3 Types of municipal water distribution layouts

Municipal water distribution layouts are designed to efficiently deliver water to urban and rural areas while maintaining system reliability and pressure. The key types of water distribution layouts are as follows:

Dead-End System:

- Also known as the "Tree System," this plan comprises a single main pipeline coupled to several sub-main pipelines that branch out to serve different locations.

- Sub-mains further divide into smaller branches to provide individual service areas.
- This system is best ideal for historical towns and cities with irregular road patterns, as it is very straightforward to design and implement.
- However, it has limits in maintaining water pressure equally and can lead to stagnation at dead ends.

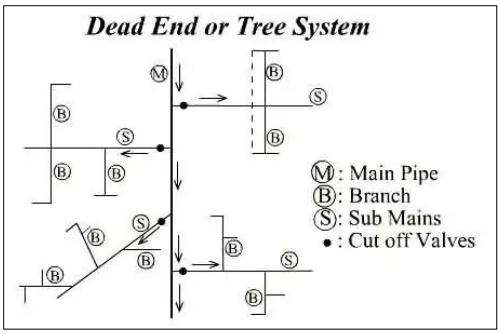


Figure 9:Dead End System

Radial System:

- In this system, the area is divided into distinct zones, each served by a central distribution reservoir or storage tank.
- Water is supplied radially from the reservoir to households, ensuring efficient distribution and ease of pressure management.
- The radial system is ideal for planned cities where zoning is clearly defined, and reservoirs can be centrally located.

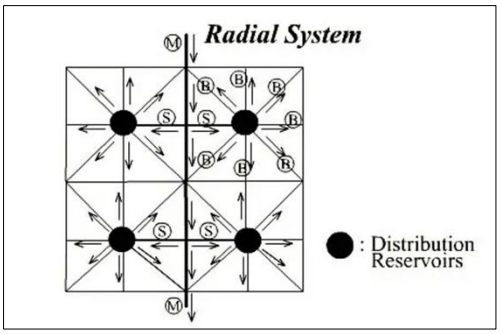


Figure 10:Radial System

Grid-Iron System:

- Also known as the "Interlaced System" or "Reticulation System," this layout interconnects main pipelines, sub-mains, and branches in a grid pattern.
- It ensures even water pressure throughout the network and provides redundancy, allowing water to flow from multiple directions in case of a pipeline failure.
- While this system requires a larger total pipeline length and is costlier to implement, it is highly effective for modern, well-planned cities with rectangular road layouts.

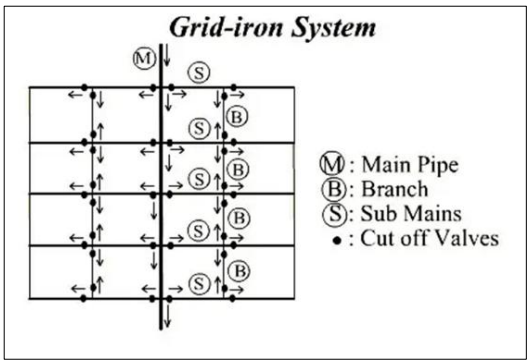


Figure 11:Grid Iron System

Ring Distribution System:

- The entire water distribution system is enclosed by a main pipeline, forming a ring-shaped layout, often in radial or rectangular patterns.
- Sub-main pipelines enclose smaller service areas within the larger ring.

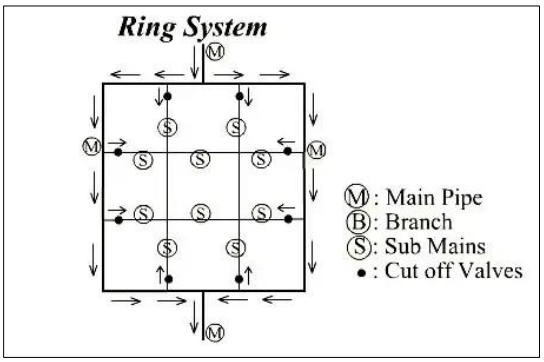


Figure 12: Ring Distribution system

- This system provides high reliability, as water can be supplied from two directions, minimizing disruptions during pipeline failures.
- The ring system requires a higher number of valves for operational flexibility, making it costlier but highly efficient for areas requiring robust supply continuity.

3.4 Basic Criteria for urban water supply system.

The planning of water supply systems relies on fundamental design parameters, including water quality and quantity, the design period, the coverage area, per capita water supply rate, additional water needs in the region, pressure requirements for piped systems, water quality standards, and the nature and location of required facilities.

Water quality and quantity

Water quality and quantity in urban supply systems can fluctuate significantly, requiring adjustments in treatment levels and resource management on seasonal, monthly, daily, and even hourly bases.

(a) Water Conservation: Effective water conservation focuses on optimizing the use of available water resources, preventing wastage, and implementing robust demand management strategies to ensure sustainability.

(b) Enhancing Water Availability and Supply-Demand Management:

- **Water Availability**: Augmenting water resources through rainwater harvesting, both on the surface and underground, is a key method to increase water supply.
- **Supply Management**: Improving supply efficiency involves minimizing losses, reducing wastage, and addressing unaccounted-for water (UFW) within transmission and distribution systems.

- **Demand Management**: Measures aimed at reducing water demand focus on the optimal utilization of available supplies, ensuring essential and desirable needs are met without unnecessary waste.

Design Period:

Water supply projects are typically planned to accommodate the requirements for a period of **30 years** after their completion. This design period ensures that the infrastructure can meet the growing demands of the population and urbanization over an extended timeframe. Specific components of water supply systems are assigned design periods based on their functionality and expected longevity, as outlined in accompanying guidelines or tables detailing their durations.

Table 2: Different design period life of water supply system as per CPHEEO. (CPHEEO, 1999)

Sr. No	Items	Design Period in (in years)
1	Storage by dams	50
2	Infiltration works	30
3	Pumping	
	(i)pump house	30
	(ii) electric motors and pumps	15
4	Water treatment units	15
5	Pipe connection to several treatment units and other small appurtenances	30
6	Raw water and water conveying means	30
7	Clear water reservoirs at the head works, balancing tanks and services reservoirs	15
8	Distribution system	30

Per Capita Water Supply:

Piped water systems should meet basic needs, including domestic uses (e.g., drinking, cooking, bathing, and gardening), institutional and public purposes (e.g., street cleaning, park watering, and sewer flushing), industrial and commercial uses (e.g., central air

conditioning), firefighting needs, and livestock requirements. Additionally, systems should account for minimum permissible Unaccounted-for Water (UFW).

Domestic and non-domestic needs:

Table 3: Recommended water supply per caoita in lpcd (CPHEEO, 1999)

Sr. No	Classification of towns/cities	Recommended water supply(lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/ contemplated	150

Institutional Needs:

Water requirements for institutions such as offices, factories, schools, hospitals, hotels, airports, railway stations, and theatres should be accounted for separately if they are significant and not already covered in existing provisions.

Table 4: Institutional requirements. (CPHEEO, 1999)

Sr.No	**Institutions**	**Water Supply (lpcd))**
1	Office	45-90
2	Factories	
	Where bathrooms are provided	45-90
	Where no bathrooms are provided	30-60
3	Schools	
	Day scholars	45-90
	Residential	135-225
	Hostels	135-180
4	Hotel	180 (per bed)
5	Restaurants	450 (per bed)
6	Hospitals (Including Laundry)	
	Number of beds not exceeding 100	340 (per bed)
	Number of beds exceeding 100	450 (per bed)
	Nurses home and medical quarters	135-225

7	Railway Station	
	Junctions and intermediate stations where mail and express trains Intermediate stations where mail and express trains does not stop Terminal railway stations	70 (with bathing facilities) 45 (without bathing facilities) 45 (with bathing facilities) 23 (without bathing facilities)
8	Airports- International and domestic	70
9	Cinema Halls and Theaters (per seat)	15

Fire Fighting Demand:

Water supply schemes should account for firefighting needs as an additional draft on the distribution system, coinciding with regular consumer water demands. For communities with a population exceeding **50,000**, the daily provision can be calculated using the formula: **100**$\sqrt{\mathbf{p}}$, where **p** is the population in thousands.

3.5 Overview of Rainwater Harvesting (RWH)

Rainwater Harvesting (RWH) is a sustainable water management technique that collects and stores rainwater for various uses, including domestic, agricultural, and industrial applications. It has been recognized as an effective method to reduce dependency on conventional water sources and enhance water security, particularly in urban and semi-arid regions.

Historical Context of RWH

Rainwater harvesting dates back thousands of years, with ancient civilizations such as those in **Mesopotamia, India, and Rome** developing techniques to capture and store rainwater. Traditional RWH systems, including **stepwells, rooftop collection, and underground tanks**, have played a significant role in water conservation.

Recent studies highlight the **growing importance of RWH** in addressing water scarcity in urban environments:

- **UNESCO (2012)** emphasizes the role of RWH in achieving **Sustainable Development Goals (SDGs)**, particularly in water-stressed regions.

Challenges & Opportunities in RWH Implementation

Challenges

- **Lack of Awareness & Policy Gaps**: Many urban households are unaware of the benefits of RWH, and policies often lack enforcement mechanisms.
- **Infrastructure Limitations**: Existing storage and conveyance systems are inadequate to support large-scale RWH adoption.
- **Variability in Rainfall**: Seasonal fluctuations in rainfall can affect the efficiency of RWH systems.

Opportunities

- **Integration with Urban Planning**: Mandating RWH in **building codes** (as per the **Nagaland Building Bye-Laws 2012**) can significantly improve adoption.
- **GIS & Remote Sensing Applications**: Leveraging **Google Earth Engine and ArcGIS** can optimize site selection for RWH structures.
- **Public Awareness & Incentives**: Government subsidies and community engagement can enhance participation in RWH initiatives.

3.6 Indicators Benchmark

The Service Level Benchmark (SLB) provided by the Ministry of Urban Development, Government of India outlines performance indicators for urban water supply systems to ensure efficient and equitable service delivery.

Table 5 Indicator benchmark (MINISTRY OF URBAN DEVELOPMENT)

Proposed Indicator	**Benchmark**	**Unit**	**Formula**
Coverage of water supply connections	100%	%	(Total number of households in the service area / Total number of households with direct water supply connection) * 100
Per capita supply of water	135 lpcd	lpcd	(Water supplied to the distribution system / Number of days in the month) / Population served
Extent of metering of water	100%	%	((Number of metered direct service connections + Number of metered public

connections			standposts) / (Total number of direct service connections + Total number of public standposts)) * 100
Extent of non-revenue water (NRW)	20%	%	((Total water produced and put into transmission and distribution system - Total water sold) / Total water produced and put into transmission and distribution system) * 100
Continuity of water supply	24 hours	Hours	—
Quality of water supplied	100%	%	(Number of samples that meet the specified potable water standards in the month / Total number of water supply related complaints received per month) * 100
Efficiency in redressal of customer complaints	80%	%	(Total number of complaints redressed within the month / Total number of water supply related complaints received per month) * 100
Cost recovery in water supply services	100%	%	(Total annual operating revenues / Total annual operating expenses) * 100
Efficiency in collection of water supply-related charges	90%	%	(Current revenues collected in the given year / Total operating revenues billed during the given year) * 100

Coverage of Water Supply Connections

- **Benchmark**: 100%
- **Formula**:

$$\text{Coverage} = \left(\frac{\text{Total number of households with direct water supply connection}}{\text{Total number of households in the service area}} \right) \times 100$$

- This indicator measures the percentage of households that are connected to the public water supply system. The goal is to ensure that all households in the service area have direct access to water, aiming for 100% coverage.

Per Capita Supply of Water

- **Benchmark**: 135 liters per capita per day (lpcd)
- **Formula**:

$$\text{Per capita supply} = \frac{\text{Water supplied to the distribution system}}{(\text{number of days in the month}) \times \text{population served}}$$

- This measures the average amount of water supplied to each person per day. The target is 135 lpcd, which is considered adequate for urban consumption.

Extent of Metering of Water Connections

- **Benchmark**: 100%
- **Formula**:

$$\text{Metering} = \left(\frac{\text{Number of metered connections} + \text{number of metered public standposts}}{\text{Total number of direct service connections} + \text{public standposts}} \right) \times 100$$

- This indicates the percentage of water connections that are metered. Full metering (100%) is ideal, as it promotes accountability and accurate billing based on usage.

Extent of Non-Revenue Water (NRW)

- **Benchmark**: 20%
- **Formula**:

$$\text{NRW} = \left(\frac{\text{Total water produced - total water sold}}{\text{Total water produced}} \right) \times 100$$

- Non-revenue water refers to the water that is produced but not billed to customers due to leakage, theft, or unauthorized connections. The target is to limit NRW to 20%, reducing water loss and increasing operational efficiency.

Continuity of Water Supply

- **Benchmark**: 24 hours
- **Unit**: Hours
- This indicator tracks the duration of continuous water supply per day. The goal is to provide an uninterrupted water supply for 24 hours, ensuring reliable access to water.

Quality of Water Supplied

- **Benchmark**: 100%
- **Formula**:

$$\text{Water quality} = \left(\frac{\text{Number of water samples meeting standards}}{\text{Total number of complaints received}} \right) \times 100$$

- The target is to have 100% compliance with quality standards, ensuring that all supplied water is safe for consumption.

Efficiency in Redressal of Customer Complaints

- **Benchmark**: 80%
- **Formula**:

$$\text{Complaint resolution efficiency} = \left(\frac{\text{Complaints redressed within the month}}{\text{Total complaints received}} \right) \times 100$$

- This indicator assesses the efficiency of resolving customer complaints. The goal is to redress at least 80% of complaints within the month they are received, ensuring customer satisfaction.

Cost Recovery in Water Supply Services

- **Benchmark**: 100%
- **Formula**:

$$\text{Cost recovery} = \left(\frac{\text{Total annual operating revenues}}{\text{Total annual operating expenses}} \right) \times 100$$

- the financial sustainability of the water supply services is measured by comparing the revenue generated to the operational costs. The aim is to fully recover costs (100%) to ensure continued investment in the system.

Efficiency in Collection of Water Supply-Related Charges

- **Benchmark**: 90%
- **Formula**:

$$\text{Collection efficiency} = \left(\frac{\text{Revenues collected}}{\text{Total billed revenues}} \right) \times 100$$

This tracks how efficiently the water utility collects its dues. The target is 90% efficiency, ensuring that most billed revenues are collected, and improving financial management.

3.7 Government schemes related to water supply

National Water Mission (NWM) (National Water Mission , 2024)

The National Water Mission, established under the National Action Plan on Climate Change (NAPCC), was approved by the Union Cabinet on 6th April 2011. It aims to address the challenges of water conservation, climate change impact, and equitable distribution of water resources across the country. The mission focuses on developing

sustainable and integrated water management practices to ensure water security for present and future generations.

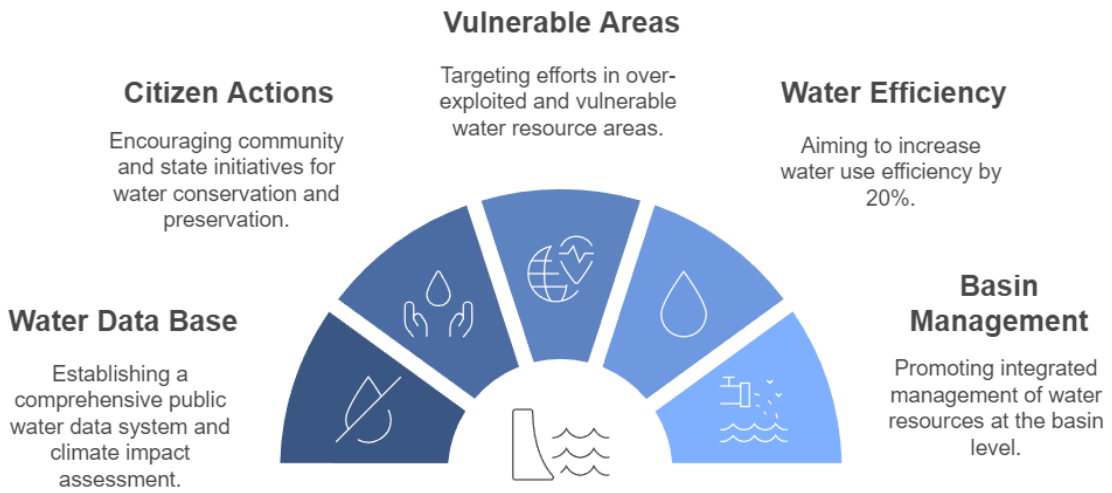

Vulnerable Areas
Targeting efforts in over-exploited and vulnerable water resource areas.
Citizen Actions
Encouraging community and state initiatives for water conservation and preservation.
Water Efficiency
Aiming to increase water use efficiency by 20%.
Water Data Base
Establishing a comprehensive public water data system and climate impact assessment.
Basin Management
Promoting integrated management of water resources at the basin level.

Figure 13: 5 goals of national water mission

The primary goal of the mission is to conserve water, minimize wastage, and promote equitable distribution through integrated water resource management across states. Its objectives include:

1. **Comprehensive Water Database:**
    - Creating a publicly accessible water database to monitor resources.
    - Assessing the impact of climate change on water availability and quality.
2. **Promoting Conservation Actions:**
    - Encouraging citizen and state-led initiatives for water conservation, augmentation, and preservation.
    - Fostering awareness and local participation in water resource management.
3. **Focus on Vulnerable Areas:**
    - Prioritizing over-exploited and climate-sensitive areas for focused interventions.
    - Implementing adaptive measures to address water scarcity in these regions.
4. **Enhancing Water Use Efficiency:**
    - Aiming for a **20% increase in water use efficiency** through advanced technologies and practices.
5. **Integrated Water Resource Management (IWRM):**
    - Promoting basin-level planning and management to ensure equitable resource allocation and sustainability.

Jal Jeevan Mission (JAL JEEVAN MISSION, 2024)

The Jal Jeevan Mission (JJM), under the Ministry of Jal Shakti, was launched by Prime Minister Shri Narendra Modi in August 2019. This initiative aims to ensure the provision of safe and adequate drinking water through individual household tap connections (Har Ghar Jal) to every rural household in India by 2024.

At the launch of JJM on 15th August 2019, only 3.23 crore rural households (16.8% of total rural households) had access to tap water connections. Since then, the mission has made significant strides, as highlighted in the graph, with the number of rural households receiving tap water increasing to 15.3 crore (73.6%) as of 28th November 2024.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT) (AMRUT, 2024)

Launched on 25th June 2015, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) aims to enhance urban living standards by improving basic infrastructure in 500 selected cities across India. This initiative covers approximately 60% of the country's urban population and focuses on creating sustainable and inclusive cities.

Key Objectives:

1. **Water Supply**: Ensure universal access to potable water with metered household connections.
2. **Sewerage and Septage Management**: Improve sanitation systems through comprehensive sewerage infrastructure.
3. **Drainage**: Reduce flooding risks with upgraded stormwater drainage systems.
4. **Green Spaces**: Promote ecological balance with the development of parks and green urban spaces.
5. **Non-Motorized Transport**: Encourage sustainable urban mobility with facilities for pedestrians and cyclists.
6. **Capacity Building**: Strengthen local governance and enhance the efficiency of urban management through training and technological support.

AMRUT 2.0 (AMRUT2.0, n.d.)

AMRUT 2.0 was launched on 1st October 2021, building on the achievements of AMRUT 1.0 and extending the mission for a further five years, from the financial year 2021-22 to 2025-26. The mission aims to expand its reach from the initial 500 cities to about 4,900

statutory towns across India, ensuring universal water supply and addressing sewerage and septage management in the cities covered in the first phase.

Key Objectives:

1. Universal Water Supply:
    - AMRUT 2.0 aims to provide universal coverage of water supply through household water tap connections. This includes improving and augmenting the water supply systems across cities and towns.
2. Sewerage and Septage Management:
    - It seeks to enhance sewerage and septage management in 500 cities, focusing on the cities covered in the first phase of AMRUT, improving sanitation infrastructure.
3. Circular Economy of Water:
    - A core objective of AMRUT 2.0 is promoting the circular economy of water by encouraging water recycling and reuse through the development of a City Water Balance Plan (CWBP). The mission emphasizes the rejuvenation of water bodies, water conservation, and integrating treated sewage into the city's water supply system.
4. Reform Agenda:
    - The mission also includes a reform agenda focusing on improving the ease of living for citizens. It aims to reduce non-revenue water (water that is produced but not billed), urban planning, and strengthening urban finance.
5. Key Features:
    - Water Source Improvement: Augmenting and improving water sources, ensuring freshwater treatment, and addressing gaps in water distribution systems.
    - Sustainability: Ensuring the sustainability of water supply in terms of both quality and quantity and promoting 24x7 water supply through the use of smart solutions like SCADA (Supervisory Control and Data Acquisition).
    - Last Mile Connectivity: Ensuring that all households receive water connections with a limit of ₹3,000 per household for the last-mile connectivity.
6. Reforms in Water Management:
    - The mission strives to reduce non-revenue water below 20%, promote the

recycling of treated wastewater to meet at least 20% of the city's total water demand, and fulfil 40% of industrial water needs at the state level.

7. Funding for Northeastern & Himalayan States:
    - Northeastern states and Himalayan states will receive 90% of the project funding from the central government under the AMRUT 2.0 scheme, ensuring equitable development across these region

3.8 Policy Framework for Rainwater Harvesting in Nagaland

Rainwater harvesting (RWH) is an important component of water resource management in Nagaland, as described in numerous state rules and ordinances. The state has developed many regulations and bye-laws to stimulate the adoption of rainwater harvesting devices, particularly in metropolitan areas like Kohima, where water scarcity is a severe issue. This chapter analyses the important rules and regulations that govern rainwater collecting in Nagaland, focusing on the Nagaland Building Bye-Laws 2012, the Nagaland Water Policy 2016, and the Nagaland Drinking Water Supply Rules 1998.

Nagaland Building Byelaws 2012(*Nagaland-Building-Byelaws-2nd-Amendment-2024-Jan222025*, n.d.)

The **Nagaland Building Byelaws 2012** mandate the inclusion of rooftop rainwater harvesting systems in new building plans. According to **Chapter 4, Section 38**, all new buildings constructed on plots measuring 100 square meters and above are required to incorporate functional rooftop rainwater harvesting systems. This regulation aims to ensure that new constructions contribute to water conservation efforts by capturing and utilizing rainwater. However, buildings with thatched roofs are exempt from this requirement, considering the impracticality of installing such systems on these structures.

Nagaland Water Policy 2016(NAGALAND WATER POLICY-2016, 2016)

The Nagaland Water Policy 2016 provides a comprehensive framework for water resource management in the state. The policy highlights the fundamental right to water for drinking, sanitation, and household usage, and it calls for integrated planning to meet water scarcity challenges. Key policy measures include:

- **Priority of Water Usage:** The policy prioritizes water allocation for drinking, sanitation, and residential usage, ensuring that these needs are addressed before other

uses.

- **Decentralized and Community-Based** Rainwater collection: The policy fosters the mainstreaming of both traditional and modern rainwater collection systems. It advocates the development of attractive incentives to encourage the adoption of RWH systems at the community level.

The policy also specifies an implementation roadmap that focuses on decentralized water management, highlighting the importance of local communities in water conservation activities.

Nagaland Drinking Water Supply Rules 1998(*Phed-Nagaland-Drinking-Water-Supply-Consumer-Rules-1998-1st-Amendment-20113*, n.d.)

The Nagaland Drinking Water provision Rules 1998 govern the procedures and pricing for water provision in the state. These laws specify the fees and charges associated with water connections, including application fees, reconnection charges, and water rates for household, commercial, and industrial consumers. The laws also stipulate penalties for late payment of water bills, ensuring that users adhere to prompt payments. The guidelines establish an organised framework for water supply management, including the provision of reservoirs and meter testing costs. These rules ensure that water supply systems are maintained efficiently and that users are compensated fairly for water usage.

Table 6: Water Tarrifs of Nagaland state PHED

Sl. No	**Item**	**Unit**	**Rate w.e.f. 01.04.2010 (in Rupees)**
1	Cost of application & MoU formats	1 No.	20
2	Application fee for new normal connection	1 No.	100
3	Application fee for temporary connection	1 No.	150
4	Reconnection application fee for defaulters	1 No.	50
5	Reconnection charges for defaulters	1 No.	250
6	Security deposit (refundable)	1 No.	1000
7(a)	**Water charges for metering system**		

	Domestic use	1000 litres	50
	Commercial use	1000 litres	100
	Industrial use	1000 litres	150
	Meter fee PM	1 No.	30
7(b)	**Non metering system**		
	Domestic consumer	1 Point	100
	Commercial consumer	1 Point	350
	Industrial consumer	1 Point	500
8	Penalty for late payment of bills		
	2nd Month		10% of arrear
	3rd Month		25% of arrear
9	Reservoir 2000 litres provided	1 No.	200
10	Meter Testing fee	1 time	50

CHAPTER 4 – CASE STUDIES

4.1 Case Study: Implementing SCADA and Smart Meters in Cha-ri Village, South Korea(*Improving Water Service through Smart Metering | Development Asia*, n.d.)

Figure 14: Key Map of Case study area

High non-revenue water (NRW) losses, seasonal droughs, and inadequate real-time monitoring defined Cha-ri Village's severe water management dilemma in Seosan City, Republic of Korea. With an NRW rate of 32%, owing mostly by old infrastructure and obsolete analog meters, the city struggled to assure consistent water delivery. Only monthly water pressure was tracked; no method for real-time flow control or leak detection existed.

In response, K-water (Korea Water Resources Corporation) started a smart metering initiative in 2016 aimed at leak-prone and drought-affected areas like Cha-ri Village. The answer was putting digital water meters with Internet-of- Things (IoT) modules in place that could send usage data four times daily. These meters provided real-time measurement of water flow, pressure, and user usage, substantially boosting transparency and system responsiveness.

A SCADA (Supervisory Control and Data Acquisition) system was linked with the city's water delivery network at the same time. This enabled automatic adjustments of flow and pressure using control valves depending on demand patterns. By establishing smaller Sub-

District Metered Areas (SDMAs), which enabled focused monitoring, enhanced pressure management, and quick identification of leaks or unusual consumption, the system also brought more finely tuned zoning at a more local level.

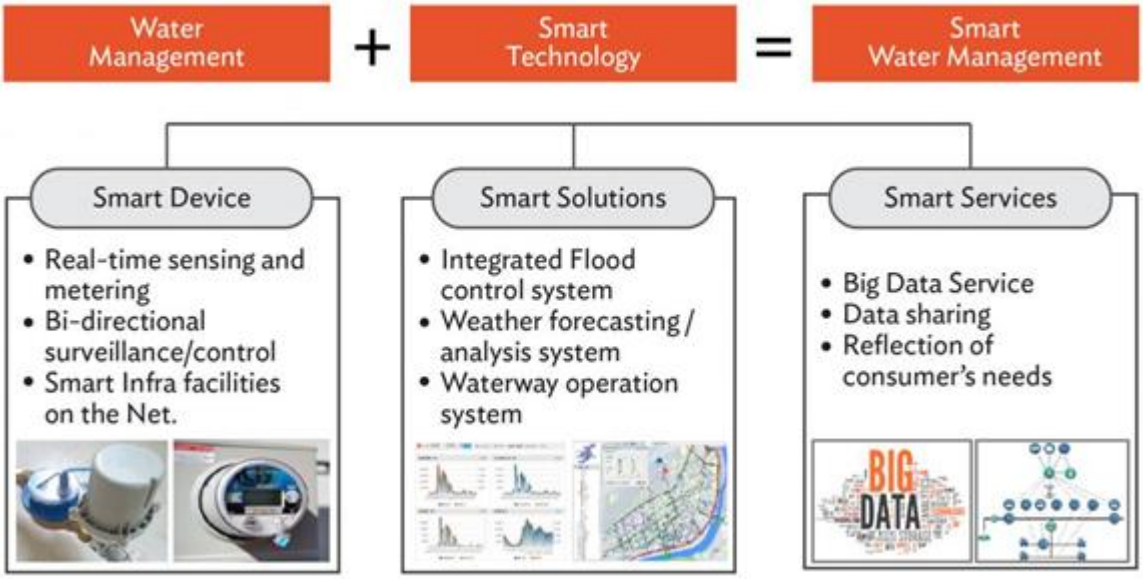


Figure 15:Smart water management integrating real-time monitoring, control, and data-driven services for efficient urban water systems

The results were rather notable. Within a short period, NRW decreased sharply from 32% to just 10%. An estimated 190,000 cubic meters of water loss per year was saved due to early leak detection and repair measures. Besides, household usage dropped by 55% and resident water costs dropped by about 70%. Financially, the initiative delivered a net saving of KRW 610 million (roughly ₹4 crore) over an 8-year duration, justifying the initial investment through long-term operating efficiency.

The system significantly improved public service delivery. With real-time diagnostics, client problems were addressed more rapidly. Users might track their water use with a smartphone application, gaining control and awareness over their use patterns. Hourly flow data even helped the city optimize supply during weekends or vacations by automatically decreasing pressure during low-demand periods.

Conclusion

The smart metering and SCADA implementation in Cha-ri Village demonstrates that real-time monitoring, zonal water management, and automated leak detection can drastically reduce non-revenue water—from 32% to 10%—while improving customer satisfaction and lowering operational costs. This case highlights how such systems can transform water governance in small urban and semi-urban areas.

4.2 Case Study: Rainwater Harvesting Mandate in Chennai, Tamil Nadu(Raghavan, n.d.)

Chennai, a coastal city in South India, depended significantly on groundwater for its water demands. Until the late 1990s, groundwater was abundant both in quantity and quality. However, increased development eliminated open spaces needed for natural recharge, leading to over-exploitation and a precipitous decline in groundwater levels. Between 1998 and 2003, despite getting adequate rainfall, Chennai suffered a serious water crisis due to the lack of rainwater harvesting (RWH) and artificial recharge technologies.

4.2.1 Problem Identification

Urbanization Effects: Shrinking open spaces inhibited natural groundwater recharge.

Water Scarcity: Although not rain-starved, Chennai suffers from serious freshwater shortages.

floods: In monsoon months, inefficient management led to urban floods.

Lack of Awareness: Both locals and government officials were unaware of the necessity of RWH.

4.2.2 Approach and Strategy

Dr. Sekhar Raghavan, through door-to-door campaigns subsequently through the setting up of the Rain Centre in 2002, led awareness and technical assistance to RWH throughout Chennai. The Centre conducted free advice to residents on harvesting rooftop runoff and driveway runoff and conducted on-site systems.

Concurrently, the Tamil Nadu Government constituted a high-level committee and initiated state-level mobilization. Awareness activities were undertaken through brochures, mobile vans, mason workshops, and local rain centres. The government legalized mandatory rainwater harvesting for new and old buildings in October 2002, the first Indian state to do so. The legislation mandated the installation of RWH within a year.

4.2.3 Methods used

Rooftop RWH: Harvesting by PVC drainpipes → filtering (sand or biosand) → masonry tanks for storing → overflow routed to recharge wells or open wells.

Driveway Runoff Collection: Rain falling on road surfaces channeled through shallow surface drainage or bump structures into percolation wells.

Artificial Recharge Structures: Cement ring wells (2.5–6 ft diameter) built depending on soil permeability and depth of water level; topped with RCC slabs for structural integrity.

Macro-scale Recharge: Restoration of temple tanks and urban lakes to hold runoff and recharge aquifers.

4.2.4 Outcomes and Impact

- Groundwater levels increased by 6 to 8 meters in different pockets of the city by 2005–2006.
- Numerous open wells, which had remained dry for years, filled up during monsoons and continued to be used.
- Municipal piped water supply became more dependable, decreasing reliance on deep borewells.
- Public awareness regarding RWH was created, and Chennai established a national model for bringing legislation, public action, and technical application together.

4.3 Conclusion

The case studies of Chennai and Cha-ri Village provide two effective yet contextually dissimilar types of water management that underscore the transformative influence of decentralized and technology-driven interventions. Chennai's rainwater harvesting initiative illustrates how widespread citizen engagement, paired with governmental mandates and low-cost infrastructure, may restore groundwater levels even in heavily urbanized and water-stressed environments. The city’s multi-scalar approach, from residential rooftops to temple tanks and recharge wells, regenerated its aquifers and enhanced the reliability of municipal supply.

In contrast, Cha-ri Village embraced a technology-led solution by adopting smart water metering and SCADA systems to reduce non-revenue water and increase operating efficiency. Through real-time monitoring, automated leak identification, and sub-district zoning, the village achieved large reductions in both physical water losses and consumer usage, while also cutting expenditures.

Together, these case studies underline the efficiency of integrated water management approaches—whether founded in traditional rainwater gathering or modern digital monitoring.

CHAPTER 5 – PARAMETERS AND TOOLS FOR ANALYSIS

5.1 Parameters

The assessment of rainwater harvesting potential in Kohima requires various datasets. **Rooftop area** is mapped using GIS, Google Earth imagery, and field surveys, while **roofing material** data (concrete, tin, tiles) is sourced from census records. The **runoff coefficient**, influenced by roofing type, is derived from literature (K.C. lalmasawmzauva & uday chatterjee, n.d.) **Rainfall data**, including annual and seasonal precipitation, is obtained from the India Meteorological Department (IMD) and Nagaland Disaster Management.

Rainwater collection efficiency considers storage and filtration losses, based on literature and expert consultations. **Water demand per household** (lpcd) is estimated from PHED reports and household surveys. **Storage capacity** data, including existing infrastructure, is gathered from household surveys and municipal records. Finally, **population data** (household numbers) is sourced from census and municipal council records.

Integrating these datasets enables a comprehensive evaluation of rooftop rainwater harvesting feasibility in Kohima

Table 7: PARAMETERS(K.C. lalmasawmzauva & uday chatterjee, n.d.)

PARAMETER	DATA REQUIRED	SOURCE OF DATA
1. Rooftop Area	Building footprints, rooftop area per household	GIS mapping, Google Earth, Field survey
2. Roofing Material	Type of roofing (concrete, tin, tiles, etc.)	Census data
3. Runoff Coefficient	Coefficient based on roofing material	Literature review (e.g., Gould & Nissen, 1999)
4. Rainfall Data	Annual & seasonal rainfall patterns (mm)	IMD (India Meteorological Department), Nagaland disaster management.
5. Rainwater Collection Efficiency	Storage and filtration losses	Literature review, Expert consultation
6. Water Demand per Household	Per capita daily water consumption (lpcd)	PHED reports, Household surveys
7. Storage Capacity	Available storage infrastructure	Household survey, Municipal planning records

8. Population Data	Number of households in study area	Census, Municipal Council records

5.2 TOOLS FOR ANALYSIS

To effectively calculate the rooftop rainwater harvesting (RWH) potential it is crucial to understand the interplay of key parameters and the analytical tools employed. The RWH potential is determined by the formula:

$$\text{RWH Potential} = P \times A \times C$$

Where,

P = Annual rainfall (mm)

A = Catchment area (m^2) (rooftop area/building footprint)

C = Runoff coefficient (based on roof material)

Table 8: Types of roof coefficient(K.C. lalmasawmzauva & uday chatterjee, n.d.)

TYPE OF ROOF	**RUNOFF COEFFICIENT**	**REFERENCE**
GI (Galvanized Iron sheet)	0.9	Manual on construction and maintenance of household-based. Thomas and Martinson (2007)
	>0.9	Thomas and Martinson (2007)
Asbestos sheet	0.8	Manual on construction and maintenance of household-based rooftop water harvesting systems, report prepared by AFPRO (Action for Food Production) for UNICEF
	0.8-0.9	Thomas and Martinson (2007)

Tiled roof	0.75	Manual on construction and maintenance of household-based rooftop water harvesting systems, report prepared by AFPRO (Action for Food Production) for UNICEF
	0.6-0.9	Thomas and Martinson (2007)
Concrete roof	0.7	Manual on construction and maintenance of household-based rooftop water harvesting systems, report prepared by AFPRO (Action for Food Production) for UNICEF
	0.9-0.95	Lancaster (2006)
Sheet metal	0.80-0.85	Gould and Nissen-Petersen (1999)
Metal	0.81-0.84	Liaw and Tsai (2004)
Aluminum	0.7	Ward et al. (2010)
Clay tile (machine-made)	0.30-0.39	Gould and Nissen-Petersen (1999)
Clay tile (hand-made)	0.24-0.31	Gould and Nissen-Petersen (1999)
Level cement stone/slate	0.81	Liaw and Tsai (2004)
Gravel	0.8-0.85	Lancaster (2006)
Organic (thatch, palm)	0.2	Thomas and Martinson (2007)

Different roofing materials exhibit varying runoff coefficients, as detailed in the diagram. For instance, Galvanized Iron (GI) sheets have a coefficient of 0.9, indicating high runoff efficiency, while organic materials like thatch or palm have a much lower coefficient of 0.2. Concrete roofs range from 0.6 to 0.9, and clay tiles whether machine-made (0.30-0.39) or hand-made (0.24-0.31) and metal roofing materials like sheet metal, aluminum are also listed, each with assigned runoff coefficients and references.

Table 9:Analytical tools(K.C. lalmasawmzauva & uday chatterjee, n.d.)

ANALYTICAL TOOL	PURPOSE	APPLICATION IN RWH STUDY
Google Earth Engine (GEE)	Remote sensing & spatial analysis	Extracting building footprints and land cover data
GIS (ArcGIS)	Spatial analysis	Mapping catchment areas and overlaying rainfall data
MS Excel	Data analysis	Calculating RWH potential for multiple buildings

To determine the components of the equation, Google Earth Engine (GEE) is utilised for extracting building footprints and land cover data through remote sensing and spatial analysis. GIS (ArcGIS) is helpful in mapping the catchment areas and overlaying rainfall data to geographically contextualize the RWH potential. Finally, MS Excel acts as a data analysis tool for estimating the RWH potential for many buildings, permitting a scaled assessment of the overall harvesting chances. By merging these techniques with reliable data on rainfall patterns, roof materials, and building dimensions, a thorough picture of the rainwater collecting potential may be produced, ultimately informing sustainable water management policies in the region.

CHAPTER 6– STUDY AREA

6.1 Study Area - Kohima

Kohima is the capital city of Nagaland, situated at 25.67° N, 94.10° E and perched at approximately 1,445 m above sea level. Governed by the Kohima Municipal Council (KMC), it covers roughly 11 km² and is subdivided into 19 administrative wards. According to the 2011 Census, the city's population stood at 99,039, with a literacy rate of 90.76 % and a sex ratio of 927 females per 1,000 males. The resident population is linguistically diverse—English (official), Angami, Ao, Chakhesang, Lotha, and Sümi—and predominantly Christian (80.22 %), with Hindu (16.09 %), Muslim (3.06 %), and Buddhist (0.45 %) minorities.(GIS Based Master Plan Kohima Capital Region Planning Area 2041 Draft Master Plan of Kohima Capital Region, n.d.)

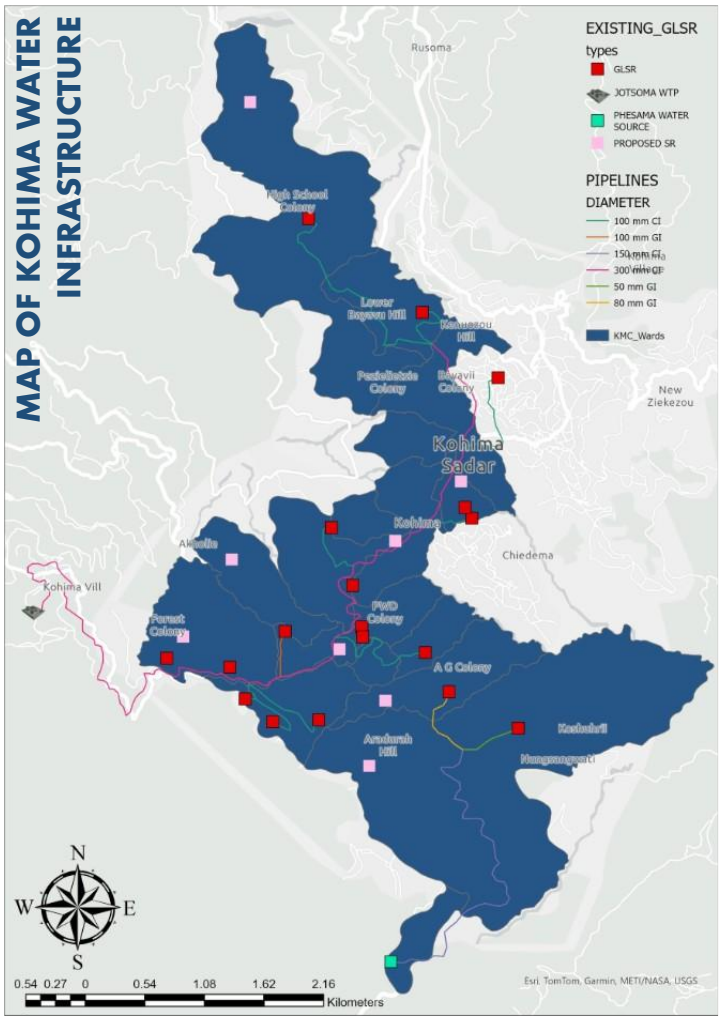


Figure 16: WATER SUPPLY MAP OF KOHIMA

6.2 Justification for Selecting Kohima as the Study Focus

Regional Piped-Water Access Comparison

As per 2011 census, among the capital cities of the six Northeastern Himalayan states, Kohima stands out for having the lowest piped-water coverage—only 38.6 percent of houses in 2011 had a direct connection to the municipal network. In comparison, peer

capitals such as Itanagar (Arunachal Pradesh) and Gangtok (Sikkim) both exceed 90 percent coverage. This gap emphasises Nagaland's systemic delivery issues and presents Kohima as the state's most significant test case for water-security solutions(census 2011, n.d.).

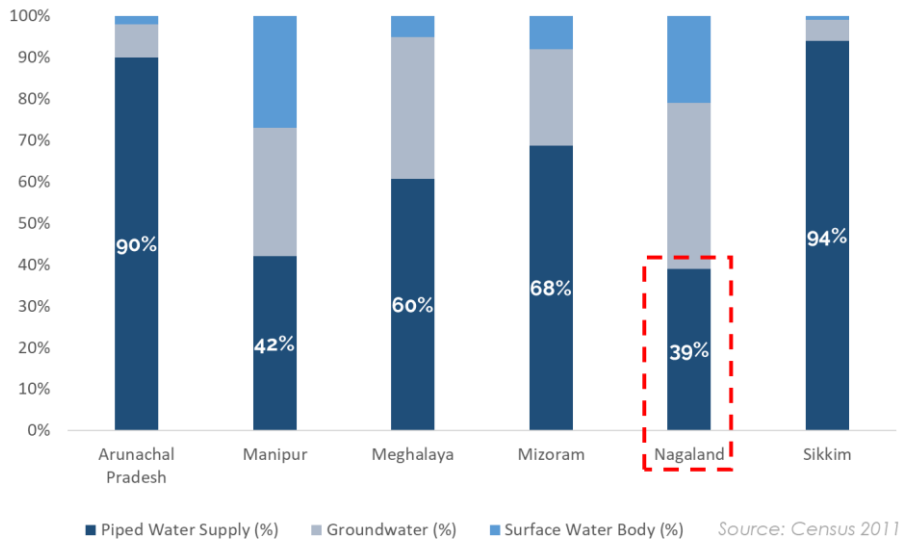


Figure 17:Bar graph showing access to piped water supply

6.3 Demand-Supply Gap and RWH Feasibility in Kohima

According to the study conducted by K.C. Lalmalsawmzauva and Uday Chatterjee(K.C. lalmasawmzauva & uday chatterjee, n.d.) on rainwater collecting potential and land reclamation in Nagaland, Kohima district demonstrates a very high disparity between water demand and supply. The demand-supply gap chart indicates that Kohima, along with Dimapur, falls under the largest deficit category, with gaps surpassing 11 million litres. This highlights a significant need for alternate or extra water sources in the district.

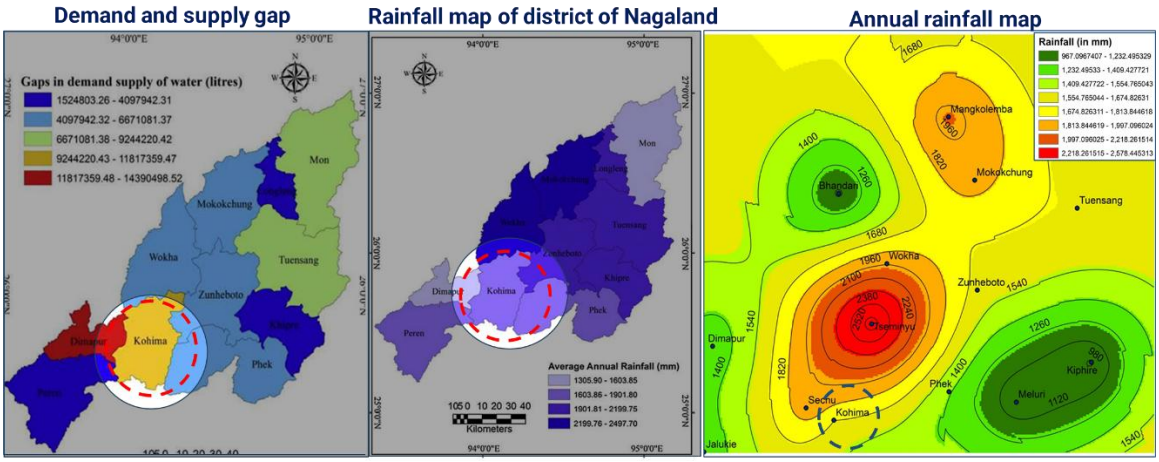


Figure 18:1. Gap of demand and supply. 2. Rainfall map of districts of Nagaland. 3. Annual rainfall map of Kohima

Area

Interestingly, Kohima also records considerably greater average yearly rainfall among the districts of Nagaland, which positions it well for developing rainwater harvesting systems. The rainfall chart of Nagaland shows that Kohima receives an annual rainfall range between 1603.85 mm and 2196.76 mm, with geographic variance across the region. Furthermore, the rainfall map sourced from the Nagaland State Disaster Management Authority reveals that Kohima is located in an area getting roughly 1780 mm of rainfall annually.

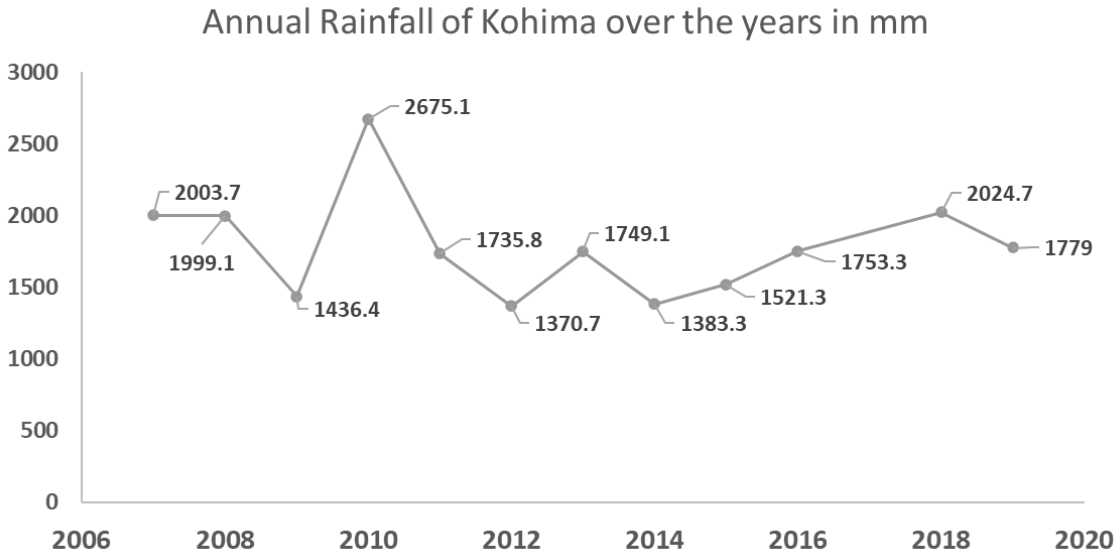


Figure 19: Annual Rainfall of Kohima over the years.(IMD, n.d.)

Despite interannual changes reported in IMD data—from a low of 1370.7 mm in 2013 to a high of 2675.1 mm in 2011—the long-term trend indicates the viability of harvesting rainwater as a sustainable approach. As per the study, the potential for rooftop rainwater collection in Kohima is substantial and can serve as a vital method to bridge the water supply gap, minimise dependence on external sources, and boost water security in the urban context.

Existing Water Supply Network

Despite its compact footprint, Kohima's piped-water network reaches only 8,852 of its 22,312 households (38.67 %), supplying about 5.6 MLD of treated water. The system draws from two gravity-fed sources—the Dzuna River (13 km away) and the Phesama Stream (7.5 km)—and stores treated flow in 19 aging reservoirs. Average per-capita supply is (Draft Master Plan of Kohima Capital), below the national norm of 135 LPCD, and is stretched further by projected demand of 35 MLD by 2041. This shortfall manifests

as seasonal shortages, intermittent service (often under one hour, twice weekly), and critical infrastructure gaps that leave much of the city reliant on private tankers and springs

6.4 Physiographic and climatic context of Kohima

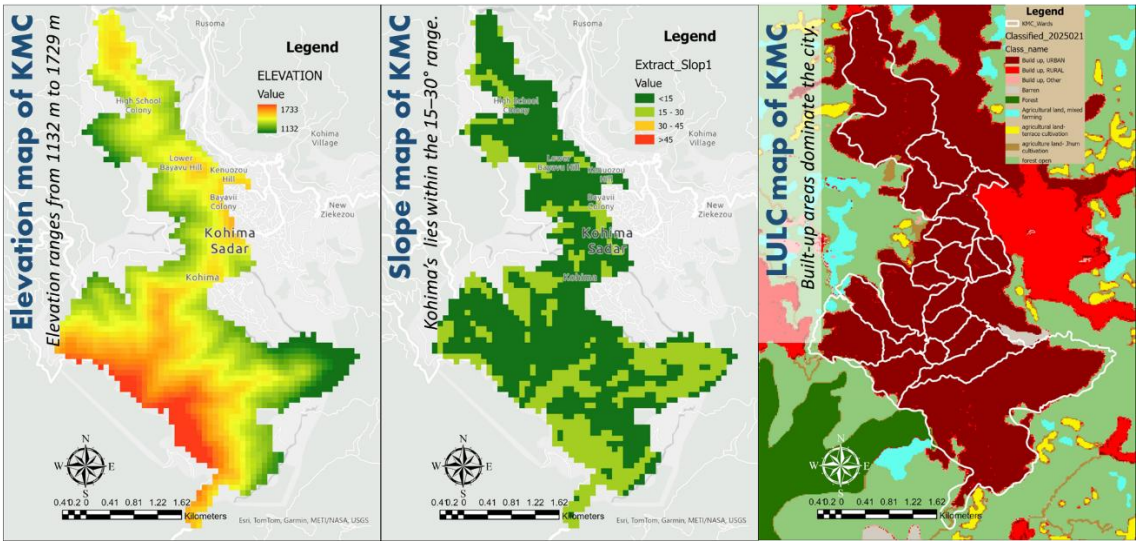


Figure 20 Elevation, Slope and LULC map of Kohima city

The Kohima Municipal Council area spans a rugged hill terrain, with elevations rising from approximately 1,132 m at the valley bottoms to 1,729 m atop the southern heights near Mount Japfü. These elevation differentials drive the city's gravity-fed distribution but complicate pipeline routing, requiring pressure management and booster pumping in upper-ward zones. Slope analysis shows that roughly 80 % of Kohima sits on gradients between 0–30 °, with the bulk falling in the 15–30 ° "gentle to moderate" bracket—ideal for urban development and rooftop rainwater harvesting; slopes up to 45 ° remain technically feasible with modern engineering. Land-use/land-cover mapping reveals that nearly 90 % of the municipality is built-up, with a dense urban core (highlighted in red) fringed by remnant forests and open spaces along the periphery

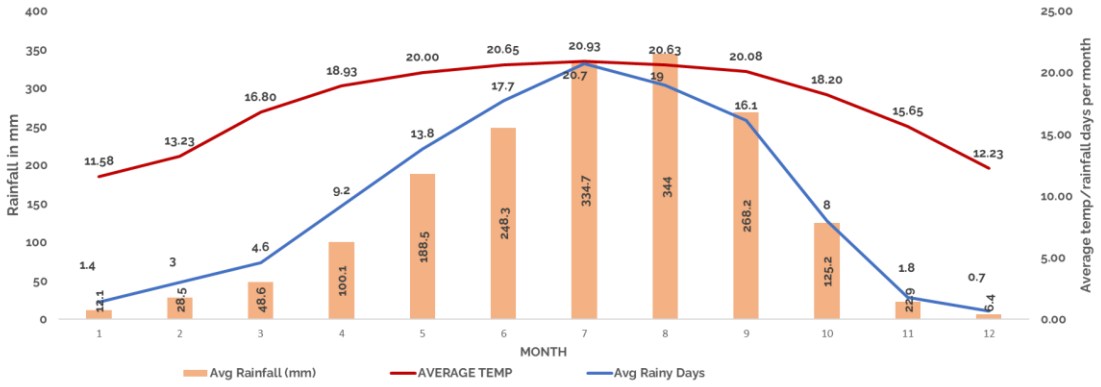


Figure 21: Rainfall chart of Kohima city

Kohima experiences a strongly monsoonal climate, receiving an average of about 1,750 mm of rainfall per year, over roughly 124 rainy days. Precipitation is heavily concentrated between May and September—when over 70 % of the annual total falls—while the December–April dry season (with monthly averages below 50 mm) coincides with acute water shortages. This pronounced seasonality underpins both the urgency of storage solutions and the high potential for capturing rooftop runoff during monsoon months (IMD, n.d.)

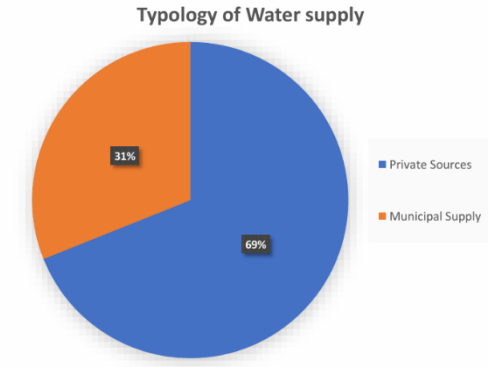


Figure 23: typology of water supply

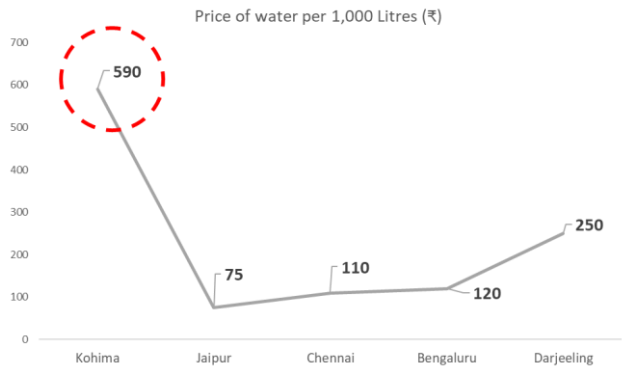


Figure 22: prices of water in different cities

6.5 Typology of Water Supply Systems in Kohima(Alinger, n.d.)

Kohima's water supply system is unique in that it operates through **four different systems**:

1. **Public Water Supply**: This system provides water to approximately **40% of Kohima's population** but at a very low per capita rate. Water is supplied **once every three days**, leading to frequent shortages.
2. **Overhead Plastic Pipe System**: This system sources water from natural springs and distributes it through an overhead network of plastic pipes. However, these

pipes have a short lifespan of **1–3 years** and are often laid over **telephone poles or private properties**, making the system vulnerable to damage.

3. **Private Water Suppliers**: Private suppliers store and distribute water to customers, often using **2,000-liter tankers** that cost **₹1,300 per delivery**. These suppliers cater to both residential and commercial customers, including government offices and army units.
4. **Government Water Procurement**: The PHED purchases water from private suppliers for **subsidized public distribution**. For example, an **8,000-liter tanker** costs **₹4,000 per month** for government use.

6.6 Current Scenario of Water Access in Kohima

The city of Kohima, with a total population of 99,039(census 2011, n.d.) and an average household size of around 4.6 persons, demonstrates large discrepancies in access to piped water. Out of the total houses, only 8,852—about 38.67%—are linked to tap water supply. The average population density across the city stands at 138 people per hectare (PPH), however this figure masks major intra-urban variances. Ward 12 and Ward 6 record the largest population densities, while the lowest availability to tap water is observed in Ward 4 and Ward 1, where coverage is barely 1% and 4% respectively. More alarmingly, Wards located in the northern areas of the city—specifically Wards 5, 6, 9, and 11—highlight a particularly serious mismatch. Despite recording high population densities averaging 220 PPH, less than 30% of houses in these locations have access to piped water. This scenario reveals serious infrastructural deficits and creates equitable concerns in the provision of crucial water supplies. The uneven access patterns underline the urgent need for targeted policy interventions and infrastructure enhancements to promote inclusive and dependable water access throughout all wards of Kohima.

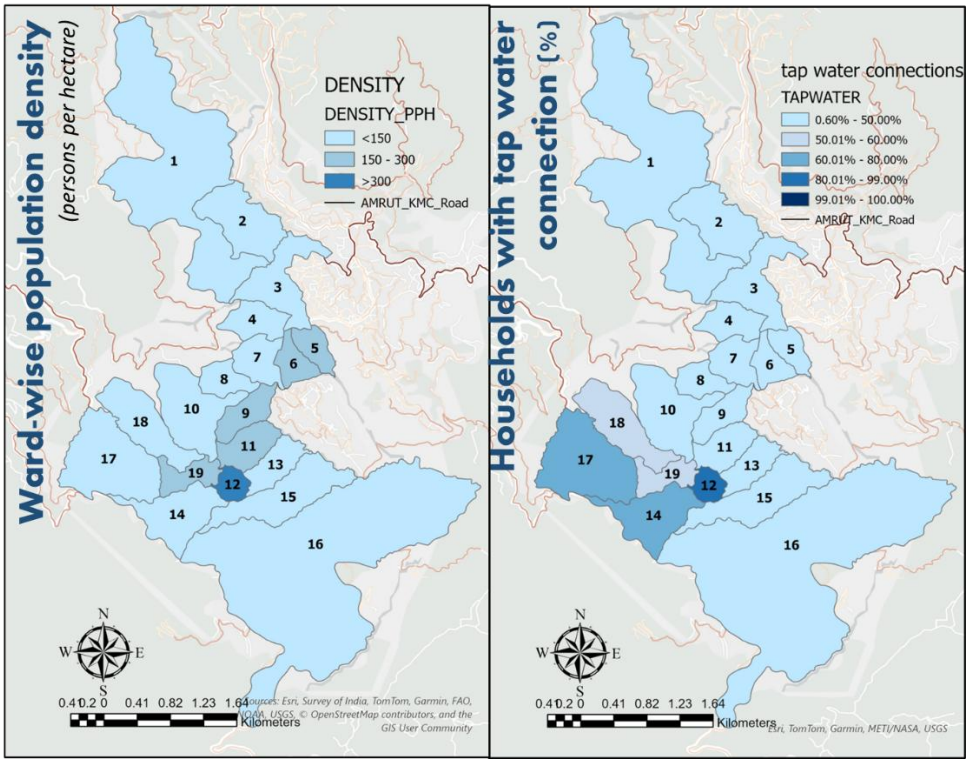


Figure 24: ward wise population density and household with tap water connections

Table 10: chart of wardwise population and wardwise household tap water connections

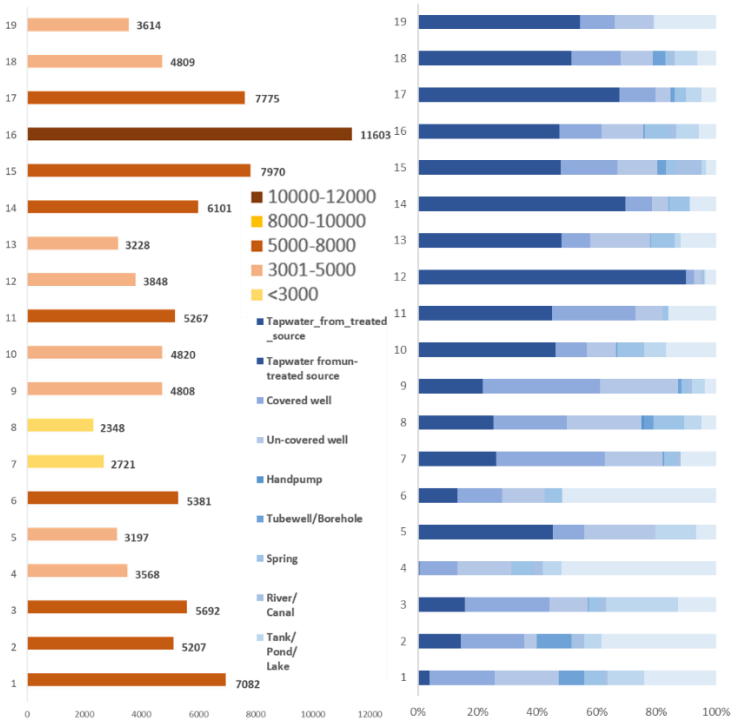


Figure 25: condition of Kohima water supply

CHAPTER 7 – ANALYSIS

7.1 Ward wise Access to Tap Water

The ward-wise analysis of water access in Kohima reveals significant spatial disparities and highlights critical areas for policy and infrastructure intervention. The coverage of piped water connections varies drastically across wards—from as low as 0.6% in Ward 4 (Naga Bazar) and 4% in Ward 1 (High School Ward), to as high as 89.8% in Ward 12 (Chandmari Upper). While the city-wide average access to tap water is only 38.6%, this number conceals stark contrasts, suggesting that service delivery is not uniformly scaled or equitably distributed(census 2011, n.d.).

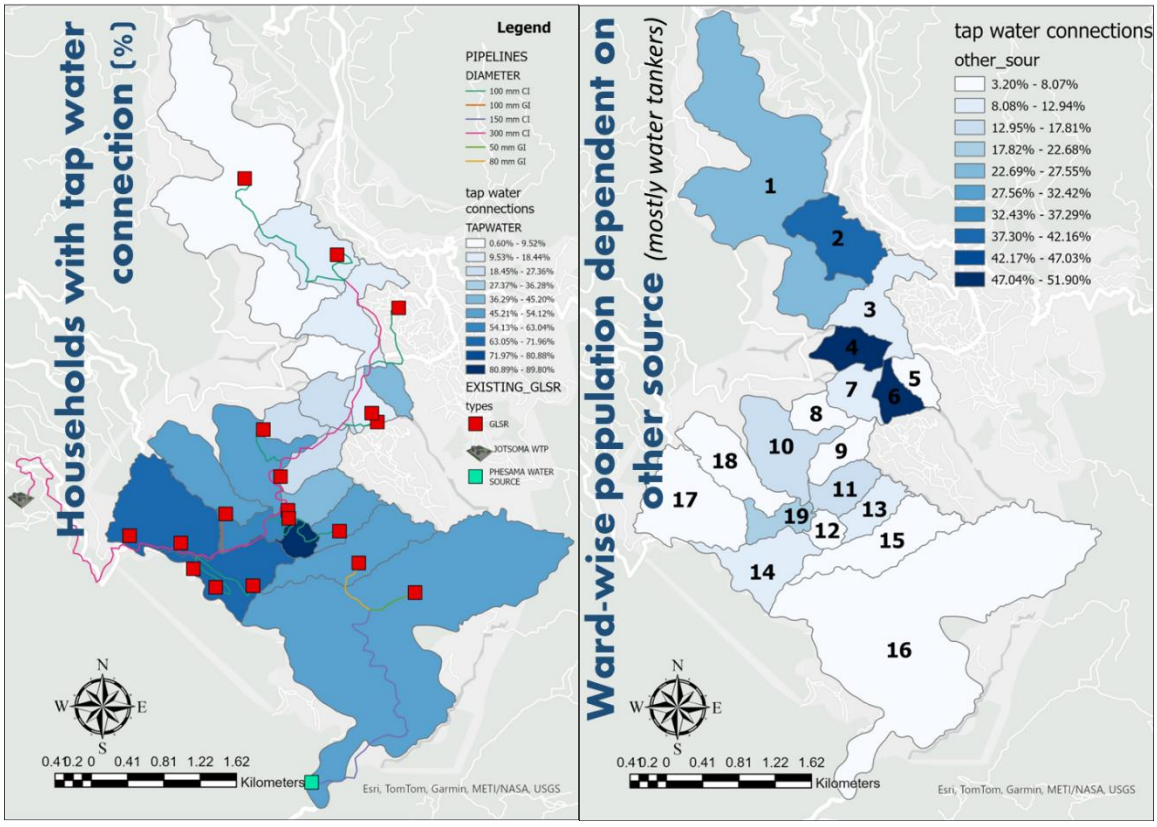


Figure 26:Household with tapwater connection vs household dependent on other sources(tankers)

Many wards, especially Wards 2, 4, and 6, show a heavy reliance on alternative sources like water tankers and spring/cable connections, with more than 50% of their supply being met through these less reliable and often more expensive means. This dependency is indicative of either infrastructural gaps in the piped network or limitations in water availability and pressure, especially in elevated or remote localities.

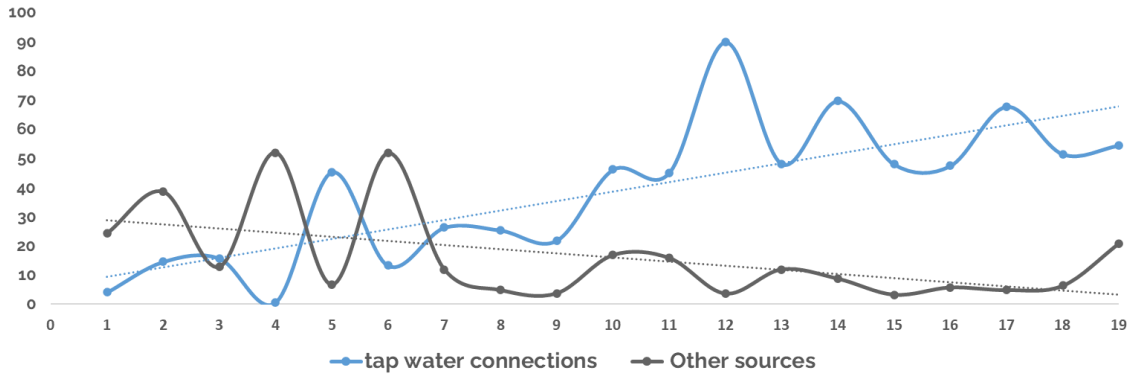


Figure 27: Tap water vs water tanks

Interestingly, the data shows no direct correlation between ward population and level of service. For instance, Ward 16, the most populous with 11,603 residents, and Ward 17 with 7,775 residents, have only moderate piped coverage of approximately 47% and 68%, respectively. In contrast, Ward 12—with a population of just 3,848—has near-universal access at almost 90%. This mismatch suggests that population size has not been a consistent determinant in the planning or expansion of the water distribution network.

Geographical proximity to key infrastructure appears to significantly influence service levels. Wards located near the Jotsoma Water Treatment Plant (WTP) and the 300 mm transmission mains—such as Wards 12, 11, and 10—enjoy better access due to lower pumping requirements and fewer transmission losses. Peripheral or higher-elevation wards, which require greater infrastructure and energy inputs, remain underserved.

Based on this analysis, Wards 1, 2, 3, 4, and 6 emerge as priority areas for targeted intervention. These could include network expansion projects, installation of decentralized systems like rainwater harvesting (RWH), and community storage tanks to improve local resilience. Addressing the disparities in these zones will be critical to ensuring equitable water access across Kohima and building a more inclusive urban water system.

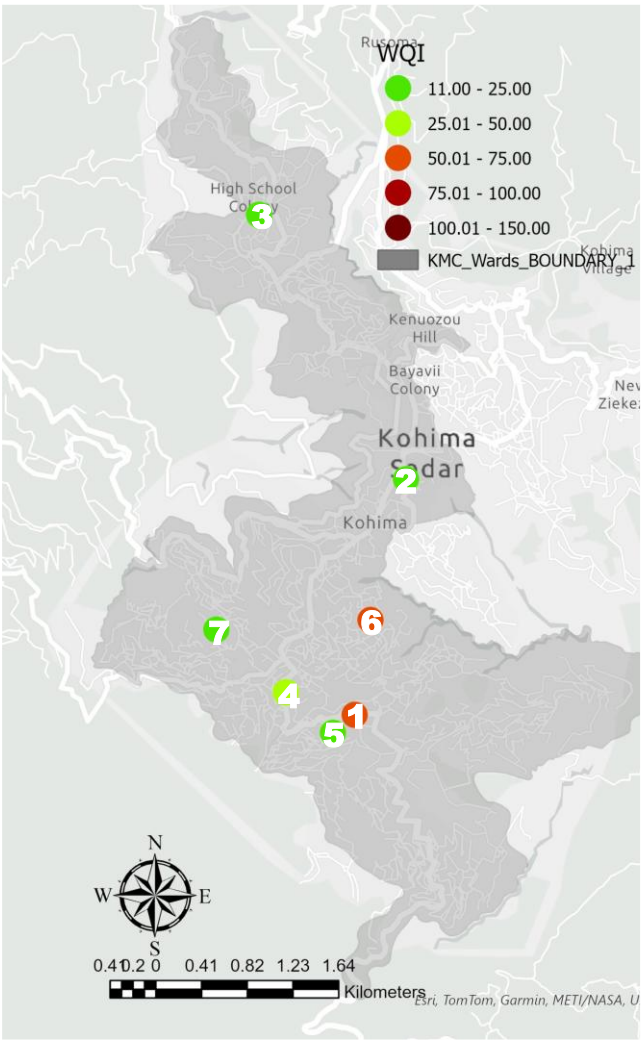
Figure 28:water tankers supply water

7.2 WATER QUALITY

The water quality assessment conducted at seven sampling points across Kohima by (Yanthan et al., 2023) reveals both spatial and parameter-specific variability in drinking water standards. Out of the seven samples analyzed, three were classified as 'Excellent' and two as 'Good', indicating that nearly 70% of the sampled sites met acceptable quality standards. However, two samples were found to be 'Poor', exceeding permissible thresholds for key contaminants.

Table 11: Water quality table

Parameter	1	2	3	4	5	6	7	AVERAGE	BIS Permissible Limit
pH	7.7	6.2	6.4	7.1	6.8	5.9	6.1	6.6	6.5 - 8.5
Temperature (°C)	16.3	15.1	15.8	17	14.2	16	15.9	15.8	No standard
Total Dissolved Solids (TDS) (mg/L)	309	250	430	514	220	288	408	345.6	500
Electrical Conductivity (EC) (µS/cm)	589	480	832	988	432	463	770	650.6	No standard
Dissolved Oxygen (DO) (ppm)	7.4	7	4.9	7.2	7.7	7.8	6.9	7.0	No standard
Total Hardness (TH) (ppm)	351	475	703	551	399	570	665	530.6	600
Nickel (Ni) (ppm)	0.080	0.014	0.012	0.006	0.011	0.012	0.013	0.02	0.02
Aluminium (Al) (ppm)	0.4	0.07	0.02	0.19	0.02	0.33	0.02	0.2	0.2
Sulphate ($SO4^{2-}$) (ppm)	34	27	53	29	22	38	42	35.0	200
Phosphate ($PO4^{3-}$) (ppm)	0.05	0.01	0.05	0.03	0.04	0.03	0.06	0.04	1
Calcium (Ca) (ppm)	1	41	49	43	57	62	142	56.4	200
Magnesium (Mg) (ppm)	23	21	45	34	14	24	30	27.3	100
Total Organic Carbon (TOC) (ppm)	0.83	0.94	2.93	1.36	1.69	1.09	1.83	1.52	No standard



Sample No.	WQI Value	Water Quality Status
1	66.98	❌ Poor
2	20.88	✅ Good
3	13.52	✅ Excellent
4	34.14	✅ Good
5	11	✅ Excellent
6	59.04	❌ Poor
7	13.63	✅ Excellent

Figure 29:WQI of samples

Of particular concern were elevated levels of aluminium—reaching up to 0.4 ppm—and high total hardness values, with some samples showing readings as high as 703 ppm. These exceedances are significant, as they pose potential health risks, especially for vulnerable populations, and also raise concerns about corrosion in distribution infrastructure and the long-term sustainability of the water supply.

The variation in quality between different locations highlights the non-uniform nature of water contamination sources—likely linked to aging infrastructure, inadequate treatment processes, or localized pollution. These findings underline the importance of routine and widespread water quality monitoring throughout Kohima. Furthermore, they point to the urgent need for site-specific mitigation strategies, including localized water treatment units, upgrading of supply pipelines, and source protection measures to ensure safe and reliable drinking water for all residents.

7.3 Projected Water Demand vs Population Growth

Kohima's current total water demand is estimated at approximately 13.3 million liters per day (MLD), while the available treated water supply is only around 5.9 MLD. This results in a significant shortfall of 7.3 MLD — a deficit of over 55%. However, this citywide statistic masks stark spatial disparities in water availability and distribution across different wards.

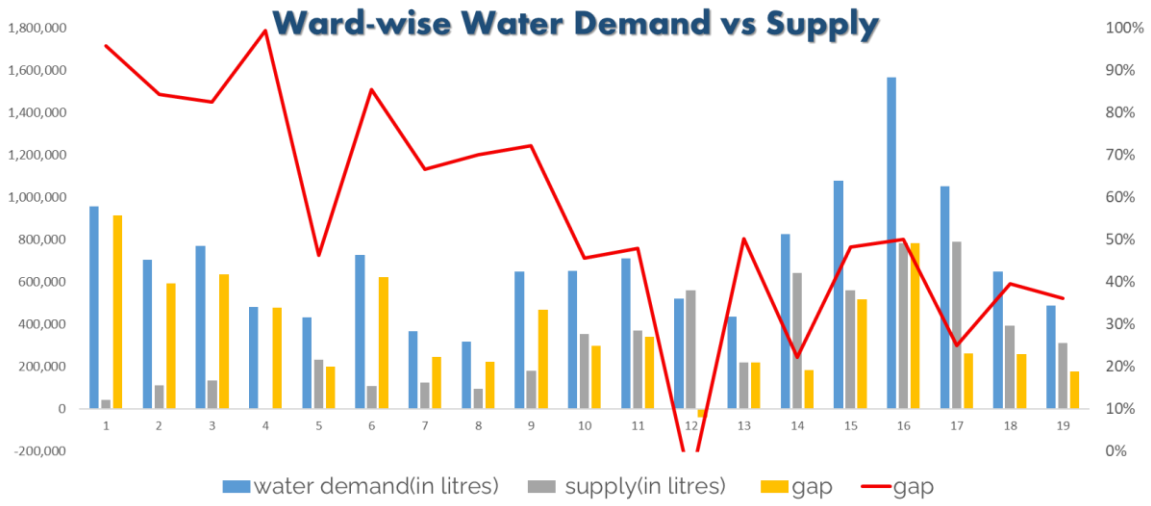


Figure 30: Ward wise wter demand vs supply

A notable pattern is that wards located in closer proximity to major water sources or water treatment infrastructure tend to experience better access and smaller supply gaps. For example, wards such as Chandmari Upper, Agri-Forest, and Hospital Colony demonstrate relatively higher piped water coverage and lower deficits due to their location near sources like the Jotsoma Water Treatment Plant (WTP) and the 300 mm main supply lines. In contrast, peripheral or high-elevation wards, particularly those located farther from core infrastructure (e.g., Wards 1, 2, 4, and 6), face disproportionately higher deficits in supply, despite often having high population densities or critical service needs.

This pattern suggests that spatial equity is not a guiding criterion in the current supply distribution. Instead, physical proximity to water infrastructure determines access — a practice that exacerbates inequalities and highlights the need for decentralized water solutions and network extensions in underserved areas.

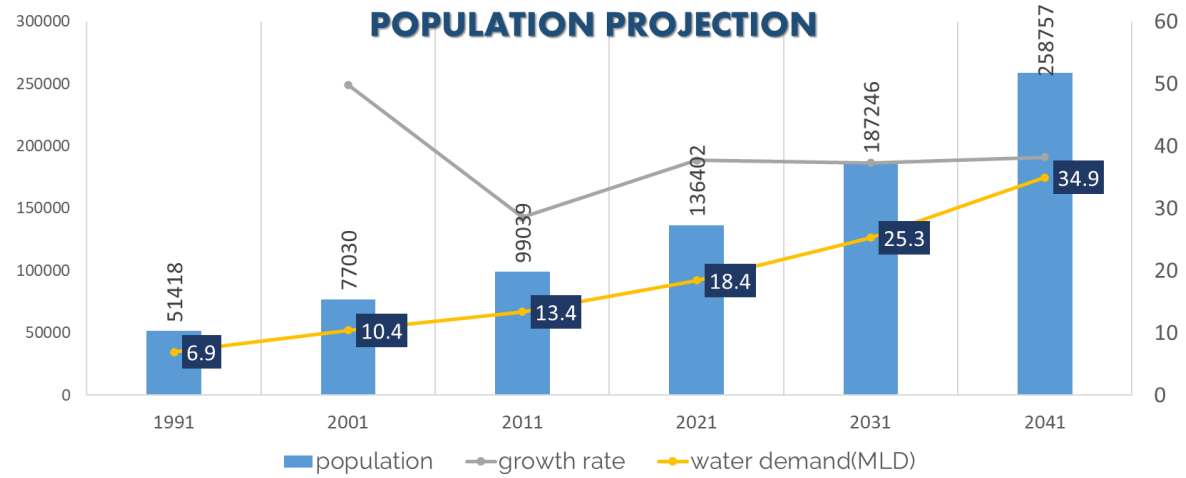


Figure 31: population projection and water demand projection

Kohima is witnessing rapid demographic expansion. Between 2011 and 2041, the city's population is projected to grow from approximately 99,000 to over 258,000 — an increase of more than 160%. This dramatic growth trajectory carries significant implications for urban water management.

In parallel with population growth, daily water demand is expected to rise nearly fivefold — from 6.9 MLD in 1991 to an estimated 34.9 MLD by 2041. When compared to the current supply capacity of approximately 6 MLD, the projected demand for 2041 indicates a staggering sixfold gap. This growing disparity underscores the urgency of enhancing water infrastructure capacity through both augmentation of supply and implementation of demand-side management measures.

Unless proactive planning and investment are undertaken, Kohima will face an acute water crisis by 2041. The projections call for strategic long-term upgrades in source development, transmission infrastructure, rainwater harvesting adoption, and water efficiency programs to sustainably bridge the demand–supply gap.

7.4 Household survey analysis

The household survey analysis offers crucial insights into the lived realities of water supply in Kohima. Based on data adapted from a study by (Bisht, n.d.), 150 households were surveyed to assess water access patterns, adequacy, and coping mechanisms. The findings indicate that a staggering 85% of households receive water supply for less than an hour, revealing severe limitations in both availability and distribution infrastructure. Furthermore, water distribution frequency is highly irregular, with only 2% receiving daily

supply and nearly 49% reporting supply just twice a week. These inconsistencies have a direct bearing on water adequacy — 72.83% of respondents reported insufficient water supply. Despite access to government supply (39.2%) and natural springs (32.5%), over half the households (53.1%) depend on water tankers, underscoring persistent infrastructural gaps.

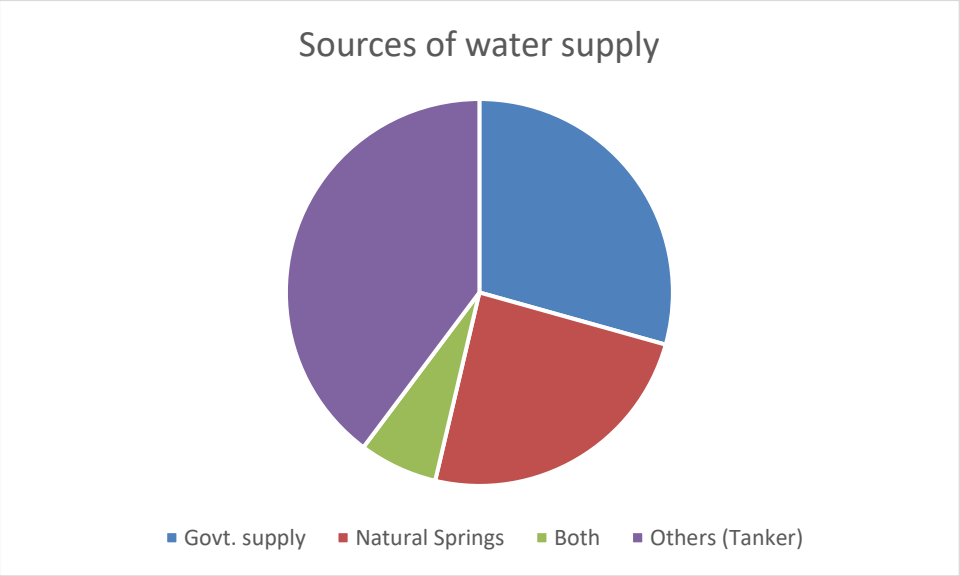


Figure 32: Sources of water supply

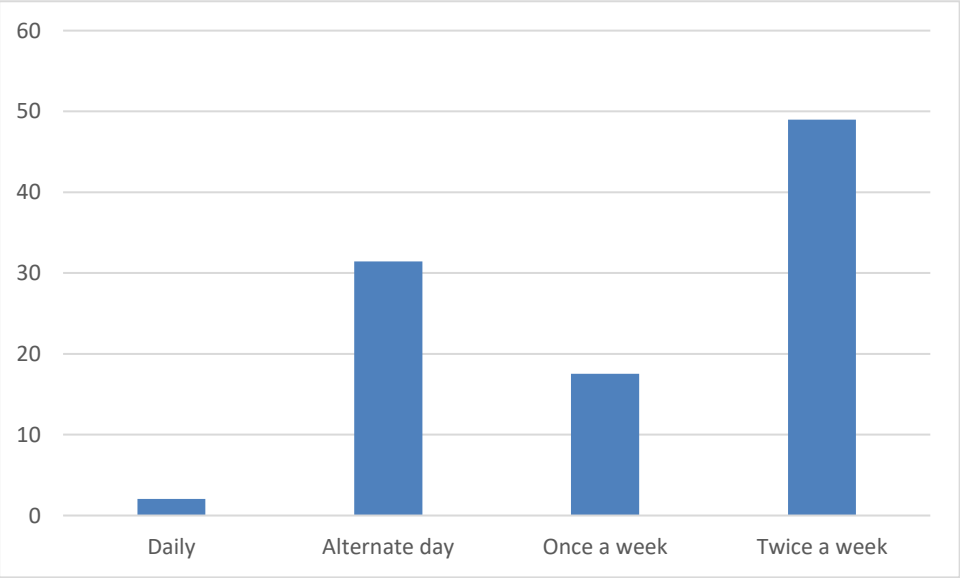


Figure 33 frequency of water supply

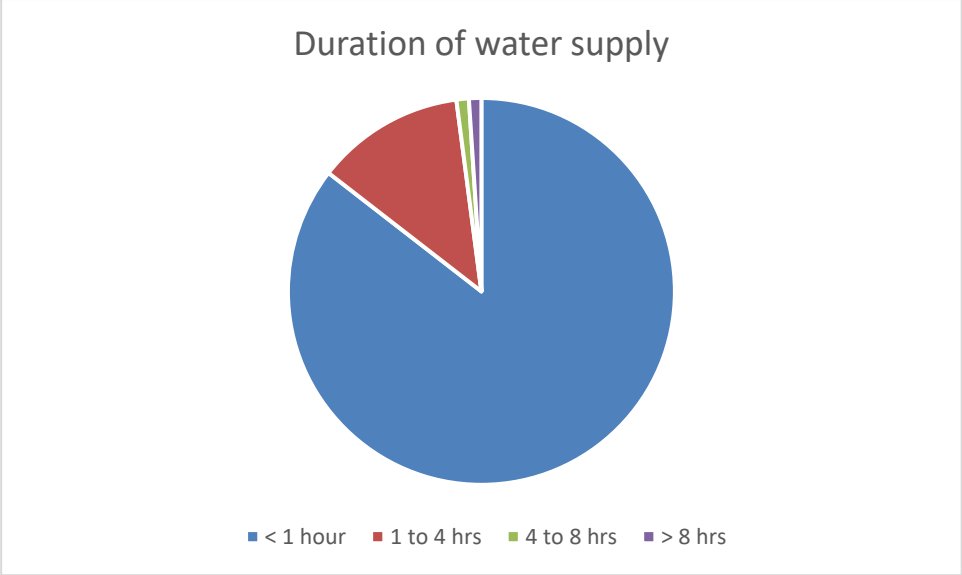


Figure 34: Duration of water supply

In response to chronic water shortages, over 77% of households cope by purchasing water from private sources, while only 6% rely on natural springs. Most families purchase between 500 to 2000 litres monthly, with nearly 26% needing over 2000 litres — a reflection of their dependence on non-governmental sources. The most critical period for water shortages is from January to April, experienced by nearly 74% of households. In terms of tanker reliance, 66.5% purchase water for 1 to 6 months annually, with the majority doing so for a 1-to-3-month duration. Only a small minority (5%) rely on tanker water year-round. These patterns point to a pressing need for both short-term relief mechanisms and long-term infrastructure reforms.

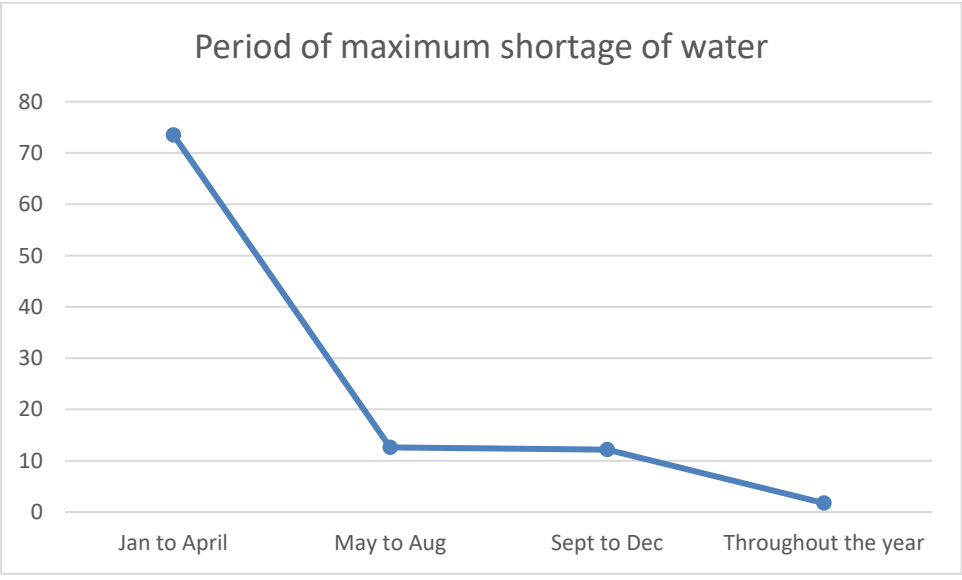


Figure 35: period of maximum shortage of water

Despite water access challenges, the adoption of rainwater harvesting is high — nearly 88% of households practice it. However, this measure only meets a partial demand, with 85% of respondents able to fulfill less than 30% of their water requirement through harvested rainwater. Moreover, community infrastructure is notably weak. While individual households make efforts toward self-reliance, nearly 78% reported no access to community reservoirs. Only 13% indicated the presence of any communal storage systems, underscoring the lack of coordinated local infrastructure. Together, these findings stress the urgency of strengthening community-level storage, improving supply equity, and promoting resilient water management strategies across Kohima.

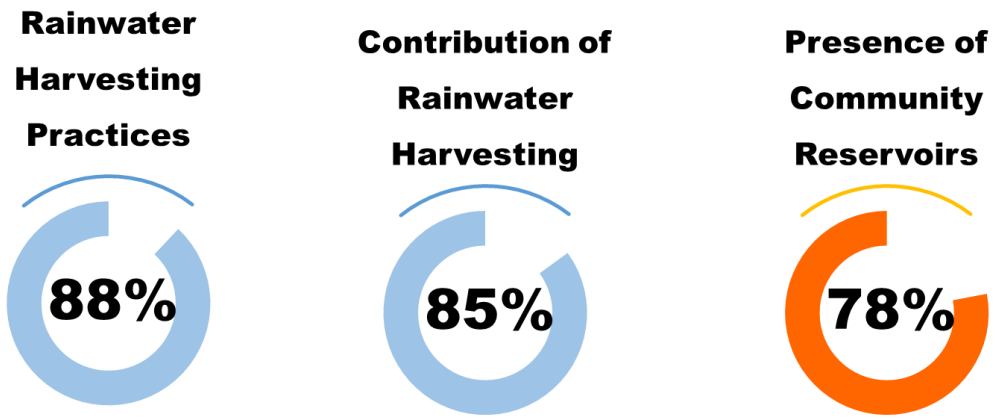


Figure 36: survey data for adoption of RHW

7.5 Rooftop Rainwater Harvesting Potential Analysis

The analysis of rooftop rainwater harvesting (RWH) potential in Kohima was carried out using digitized building footprints generated via Google Earth Engine. A total rooftop area of approximately 2.74 km² was mapped across 19 municipal wards. The digitization process involved the identification and vectorization of rooftops from high-resolution satellite imagery. The majority of rooftop surfaces were found to be composed of GI/ABS sheets (72.5%) and concrete (21.2%), both of which are highly efficient in capturing rainwater, with an average runoff coefficient of around 0.85. Other materials such as thatch, plastic, tiles, brick, and stone-slate make up less than 5% of the total and contribute significantly less due to lower runoff efficiencies.

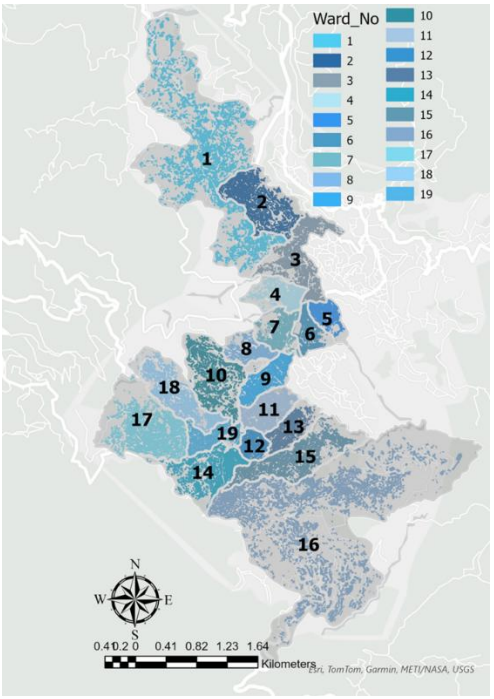
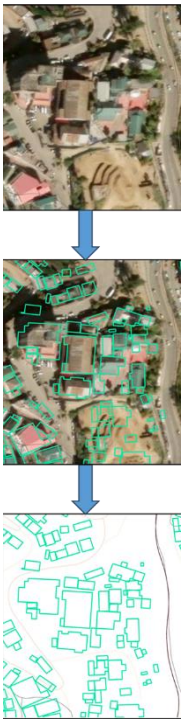


Figure 38: Building Footprint map of Kohima City



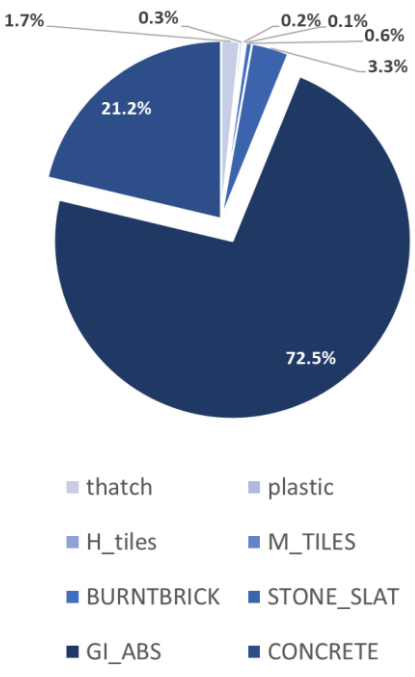
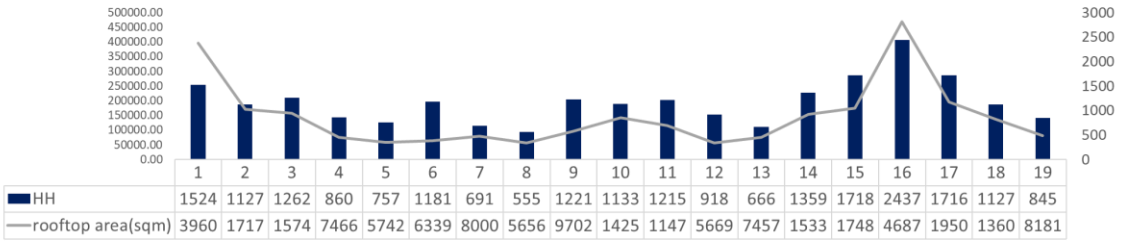


Figure 37: percentage share of roofing materials

For effective augmentation, it is recommended to implement targeted RWH infrastructure like storage tanks and recharge pits, particularly in wards with the highest concentration of rooftop area, such as Wards 1, 16, and 15. Additionally, minor retrofitting efforts on GI/ABS and concrete rooftops could yield substantial water savings at a relatively low marginal cost. The spatial distribution shows that Wards 5, 16, and 13 have some of the largest rooftop areas and thus the highest potential for rainwater harvesting.

Table 12: data showing number of households per ward and rooftop area



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HH	1524	1127	1262	860	757	1181	691	555	1221	1133	1215	918	666	1359	1718	2437	1716	1127	845
rooftop area(sqm)	3960	1717	1574	7466	5742	6339	8000	5656	9702	1425	1147	5669	7457	1533	1748	4687	1950	1360	8181

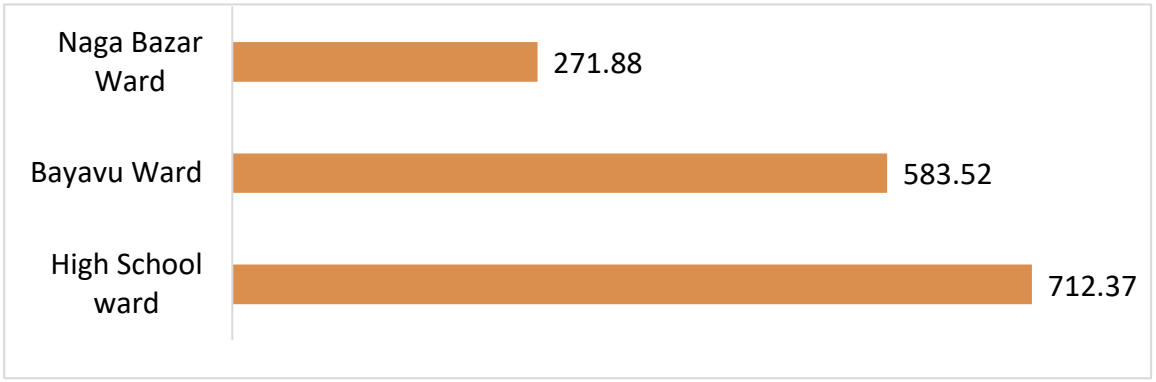
Using the digitized rooftop areas, combined with Kohima's average annual rainfall of 1,750 mm and runoff coefficients ranging from 0.7 to 0.9, the estimated annual rooftop rainwater harvesting potential is approximately 4,121 million liters (ML). With rainfall occurring over roughly 116 days per year, this equates to an average daily harvest potential of about 35.53 million liters. This figure significantly exceeds the projected daily water

demand of Kohima city, which was 18 MLD in 2021.

$$\frac{4{,}120{,}932{,}097L}{116\ days} = 35{,}525{,}276L/day$$

The harvesting potential is highly seasonal, with 75% of the total yield occurring between May and September, aligning with the monsoon period. The highest rainfall and corresponding harvesting potential are observed from July to August (344 mm). Conversely, December to January experiences very low rainfall (<30 mm), making storage planning essential to address supply gaps. Survey data reveals that 73.48% of water shortages in Kohima occur from January to April, underscoring the importance of strategic storage and distribution planning

Table 13; top 3 RHW potential ward



The top three wards with the highest RWH potential are the High School Ward (712.37 ML), Bayavu Ward (583.52 ML), and Nga Bazar Ward (271.88 ML), making them prime candidates for initial implementation and pilot projects in rainwater harvesting infrastructure.

CHAPTER 8 – PROPOSALS

8.1 Upgradation and Rationalization of existing Water Infrastructure

Kohima's water distribution system is poorly planned, highly scattered, dependent on ageing and frequently improvised equipment. Census 2011 data shows that just 38.6% of Kohima Municipal Council (KMC) area homes have piped water connection. With piped penetration as low as 1%–4% in some areas, field observations and ward-wise geographical analysis found that regions including Ward 1 (High School), Ward 4 (Naga Bazar), and Ward 6 suffer from quite limited access. Topographical restrictions, population increase, and infrastructure degradation aggravate these restrictions and result in too much reliance on unofficial spring-based systems and private water tanks.

The present system's physical architecture calls for overhead plastic pipes, usually placed across facades over private land, across utility poles, and across buildings. These connections lack pressure management, are prone to leakage, and are not formally monitored or mapped. As a result, non-revenue water (NRW) in the city is 30%(2009), adding to supply losses and financial inefficiencies for the Public Health Engineering Department (PHED).

As Kohima's population is anticipated to grow ~25,80,00 by 2041, this plan offers an integrated infrastructure intervention centred on:

- Replacing and restructuring the existing distribution system,
- Expanding service reservoir capacity to fulfil CPHEEO regulations,
- Enhancing system resilience, coverage, and efficiency up to 2035.

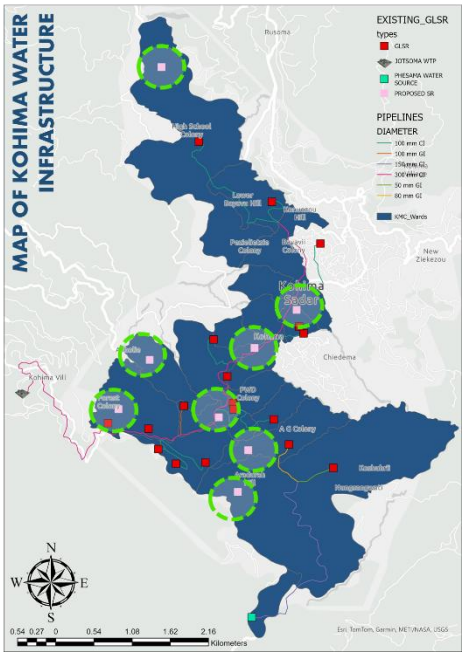


Figure 39 Proposed reserviours of kohima water supply

8.1.1 Existing Challenges

Pipeline Network Issues

- Majority of pipelines are composed of plastic or old GI, placed without official

planning.

- Unregulated overhead pipelines, conducted through utility poles and private land.
- High elevation variability generates pressure imbalances and unequal supplies.
- Frequent leakages, illicit tapping, and water loss are widespread.
- No zoning system or real-time monitoring technologies exist.

Inadequate Storage Infrastructure

Kohima now has 18 service reservoirs, with capacities ranging from 50,000 to 2,00,000 litres.

Assuming an average capacity of 125,000 litres, total existing storage is only 2.25 million litres (2.25 ML). For an anticipated population of 2,58,757, the 12-hour (50%) storage required is:

Demand: 2,58, 000 × 135 LPCD = 34.83 MLD

Required storage: 0.5 × 34.83 = 17.42 MLD

Demand: 258,000×135 LPCD=34.83 MLD

Required storage: 0.5×34.83=17.42 MLD

Current storage satisfies only ~12.9% of the needed capacity, leaving a shortage of ~15.17 MLD.

8.1.2 Recommended Interventions

Pipeline Rationalization and Rehabilitation (2025–2032)

- Map existing pipelines and pressure regions as part of a GIS-based infrastructure analysis.
- Ductile iron (DI) pipes must replace old and informal pipelines HDPE or otherwise.
- Implement hydraulic zoning based on the elevation levels
- Target priority wards like Wards 1, 2, 4, 5, and 6.

Service reservoir capacity expansion (2026–2035)

- To meet the 17.42 MLD need, introduce around 100 new service reservoirs.
- Concentrate on 100–200 KL capacity modular RCC reservoirs.
- Give placement in top priority in:
    - High-elevation and high-density zones (Wards 1, 6, 13, 16)
    - Wards 2, 4, 9, the poor and peripheral
- New SRs will support pressure balancing, standby backup, and facilitate 24×7

supply testing.

Monitoring, Pressure Regulation, and Leak Maintenance (2028–2035)

- Install PRVs (pressure-reducing valves), air valves, and bulk meters at critical nodes.
- Establish mobile leak-detection teams that utilize acoustic and GPS-enabled equipment.
- Tag the pipes and reservoirs with GIS coordinates for future integration with SCADA/smart metering.

8.1.3 Policy and Planning Recommendations

- Enforce updated KMC construction bylaws to standardize durable plumbing materials.
- Allocate 20% of PHED's urban water budget to maintenance and leak control.
- Identify public land (e.g., school roofs, govt campuses) for decentralized SRs.
- Initiate a detailed NRW research, as current data is not available.
- Link future growth plans with smart metering and SCADA rollout.

8.2 Comprehensive Decentralized Rainwater Harvesting Strategy for Kohima

Kohima's monsoonal environment, defined by an average annual rainfall of approximately 1,750 mm during roughly 116 rainfall days, is a large yet untapped resource for urban water supply. Despite this plentiful precipitation, only 38.6% of residences in the Kohima Municipal Council (KMC) area are connected to the piped network, leaving much of the city dependent on pricey private tankers, sporadic spring feeders, and informal plastic piping. Simultaneously, the rooftop catchment study has showed a theoretical capacity to harvest over 4,121 million litres per year, enough to cover the city's current average daily demand (≈ 18 MLD) and to make a considerable contribution toward the predicted need of 34.83 MLD in 2041. This plan describes a citywide, multi-tiered rainwater harvesting (RWH) framework—spanning individual rooftops to community tanks and integrated service reservoirs—to increase supply, reduce tanker dependence, and boost resilience against dry-season shortages.

8.2.1 Technical Framework

Household-Level Harvesting Mandate

To institutionalise RWH, the Nagaland Building Byelaws must be revised to mandate every new or remodelled building with a roof area above 50 m² to install a minimum 5 m³ storage tank equipped with a first-flush diverter and coarse filter. This threshold strikes a balance between economies of scale and practical application in Kohima's varied geography. A 50% capital subsidy—covering both tank purchase and installation—will be granted to families, coupled with a tariff refund of ₹2 every cubic meter of harvested rainwater utilised, motivating consumption and upkeep.

Community-Scale Storage

While household tanks address individual needs, community-scale tanks (≥ 50 m³) are required to support multi-family compounds, schools, health centres, and ward offices. Each of the 19 wards will host at least one community RWH tank, ideally sited near public buildings with extensive rooftop catchment areas. These tanks will contain sedimentation chambers, UV sterilisation ports, and overflow exits directed to adjacent recharge pits or soakaways. Community tanks not only supply water for non-potable requirements (e.g., gardening, cleaning) but also create buffer reserves for lean months.

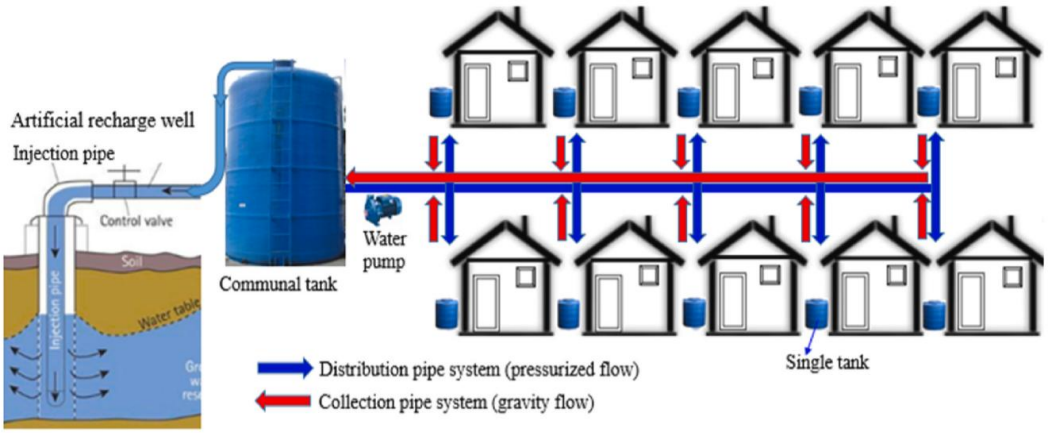


Figure 40:Illustration of the community rainwater harvest system model.

Integration with Service Reservoirs

As outlined in Proposal 1, roughly 100 new service reservoirs (SRs) are proposed to be built, each 100–200 kL in capacity, to achieve the CPHEEO-mandated 12-hour storage level (≈ 17.42 ML total). A minority of these SRs—particularly those in high-yield wards (1, 15, 16)—will be constructed as dual-use tanks, accepting both treated water from the network and captured rainfall. Dual inlets, first-flush systems, and separate distribution valves will allow safe mixing and prioritised utilisation of rainwater during the monsoon months, therefore safeguarding treated supplies for the dry season.

8.3 Water Supply Augmentation from Zaru River and Future Source Identification

Kohima is now using the Zaru River close to Mima village as additional water supply. Recent estimates indicate that following over a decade of delay, the long-awaited pumping-based augmentation project started in March 2021(East Mojo, n.d). Although this represents notable advancement, the system's reach is still restricted and insufficient to satisfy Kohima's long-term need. Although the Zaru River's capacity and sustainability particularly during the dry season remain unquantified in the public domain, the predicted water demand for the city in 2041 is 34.83 million litres daily (MLD).

Several restrictions limit the Zaru River's ability to be the only augmenting supply. First, thorough hydrological data on its discharge capacity, flow seasonality, and turbidity levels is lacking. Second, the present phase limits its scalability since there is no city-scale water treatment facility connected with it. Thirdly, among the most water-deficient areas in Kohima, the pipeline network does not reach the high and peripheral wards. These gaps point to the immediate necessity for a Phase II extension of the Zaru system as well as the building of a new water treatment facility and a redesigned distribution network.

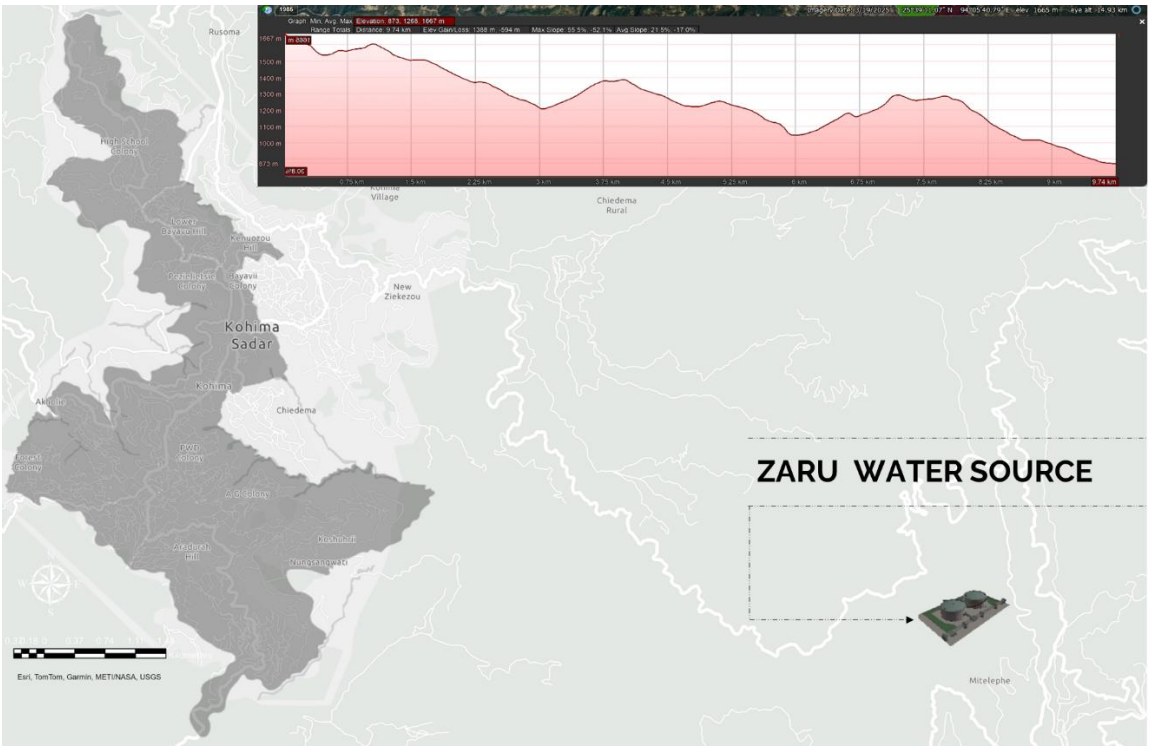


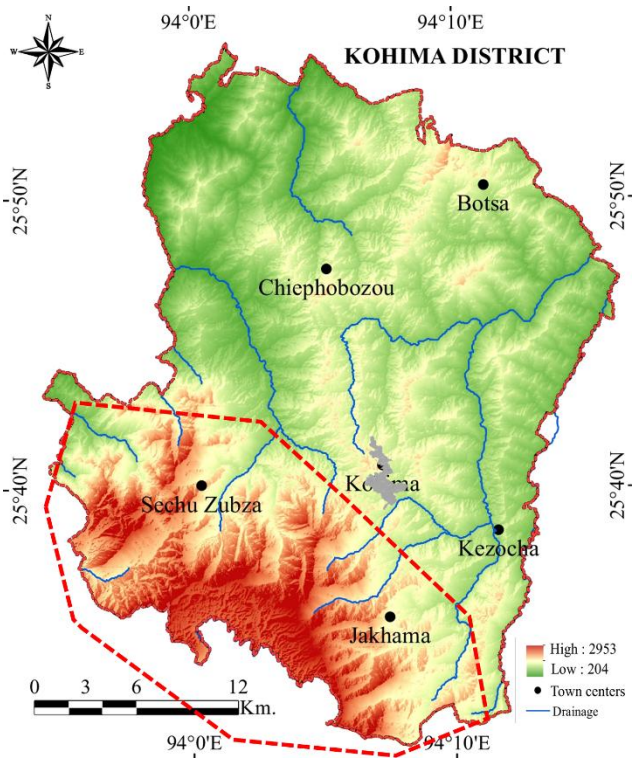
Figure 41: Map of Zaru water source

8.3.1 Proposed Actions for Zaru River Phase II

Comprehensive hydrological yield analysis, sediment load studies, and dry-season flow assessments help to maximise the Zaru system's usefulness. The distribution network should be expanded to serve outlying and high-altitude wards. A dedicated water treatment plant (WTP) should be erected near the input site, complete with sedimentation tanks, filtering systems, and disinfection facilities. The enhanced network should be connected to newly proposed service reservoirs in low-access zones, as specified in Proposal 1.

8.3.2 Identification and Study of Future Water Sources

Recognizing the constraints of reliance on a single river source, this proposal also advises a staged examination of other water sources. Several rivers within Kohima's surrounding watershed, including Dzükou, Khonoma, and Jakhama area, should be explored through extensive hydro-geological and environmental studies. These studies should involve year-round flow monitoring, water quality tests, and sediment load assessments to evaluate appropriateness for municipal supply.



In addition, the idea of inter-basin water transfers from adjacent higher-yield basins should be examined, particularly those with lower present extraction pressures. These feasibility studies must be supplemented by environmental impact assessments (EIA), financial cost–benefit analysis, and stakeholder engagement.

Parallel to surface water alternatives, groundwater mapping in Kohima's intermontane valleys and low-gradient areas should be done in conjunction with the Central Ground Water Board (CGWB). Although groundwater is often limited in hill terrains, small aquifers and springs could provide seasonal support if scientifically managed.

8.3.3 Institutional and Policy Measures

A specialised Source Development and Planning Unit within PHED should be established to handle technical, financial, and policy components of new water source development. Catchment protection rules should be implemented to prevent environmental deterioration near intake stations. These projects must be included within the Kohima Master Plan 2041, with suitable zoning and land allocation for future water infrastructure.

8.4 Smart Metering and SCADA Integration for Kohima Water Supply

Kohima runs right now without a centralised water monitoring system. The water distribution system of the city does not include real-time data on flow, pressure, leaks, or use. The Public Health Engineering Department (PHED) is greatly hampered in its capacity to monitor consumption trends, bill fairly, identify leaks, or properly manage supply zones by almost absent household-level water metering. Especially in peripheral wards where unofficial and unmetered connections are frequent, this absence helps to explain high levels of unaccounted-for water and non-revenue water (NRW).

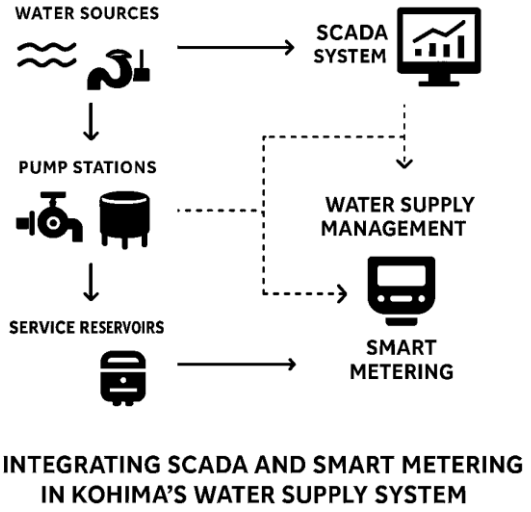


Figure 42: A schematic of Water metering and SCADA

Smart Water Metering and SCADA (Supervisor Control and Data Acquisition) is suggested to modernise and maximise Kohima's water governance system. Essential for a growing urban population and increasing service area, this dual intervention will offer a backbone of digital infrastructure to monitor, analyse, and control water distribution effectively.

8.4.1 Smart Water Metering

Smart water meters will be incrementally installed at the household, business, and institutional levels according to this component. Real-time water use will be recorded by these meters, which also wirelessly send data to a central dashboard. Tamper alerts,

optional prepayment features will be standard on them. The information will enable usage-based charging systems, help lower NRW, and spot illegal tapping.

Typical Smart Water Meter System
A wire runs from the water meter inside the home to a communications module located outside the home which in turn wirelessly communicates interval data to the smart electric meter. The smart electric meter later sends the data back to the utility.
Water Meter
Communications Module
NEPTUNE
Water Use

Figure 43:Typical smart water metering system

The meters will be linked to a cloud-based billing system, allowing citizens to see usage data, receive notifications, and make digital payments via a mobile interface.

8.4.2 SCADA for Water Infrastructure Monitoring

SCADA system will be implemented to provide real-time control and monitoring of the city's water infrastructure. This will comprise service reservoirs, pipeline networks, pressure zones, and water treatment plants. Field devices such water pressure transducers, ultrasonic flow meters, and automatic chlorination systems will feed data to a central control centre, suggested to be placed at the PHED headquarters or at the largest service reservoir cluster in the city.

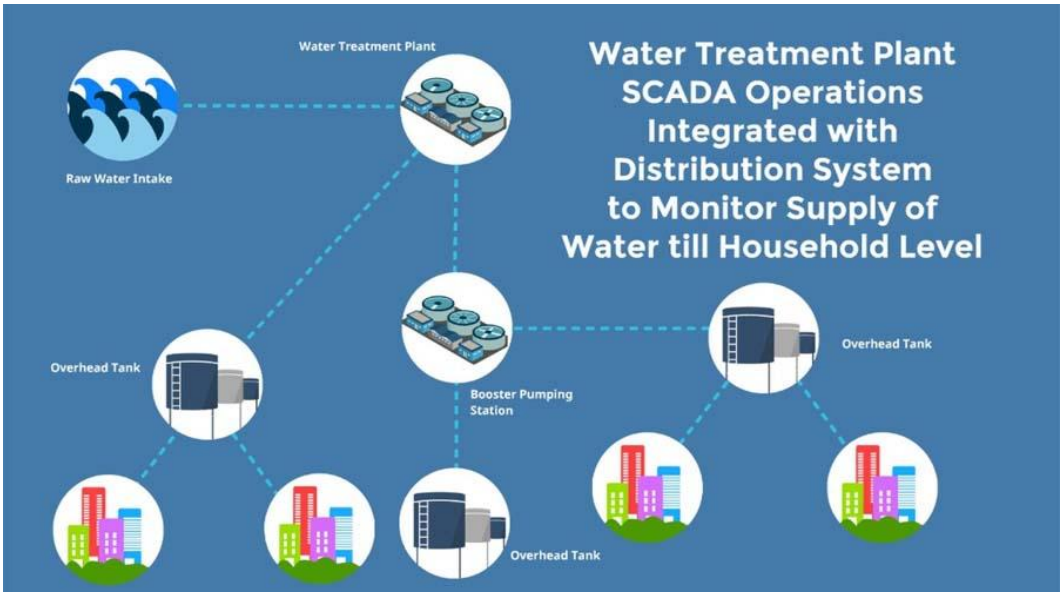

Water Treatment Plant
Water Treatment Plant SCADA Operations Integrated with Distribution System to Monitor Supply of Water till Household Level
Raw Water Intake
Overhead Tank
Booster Pumping Station
Overhead Tank
Overhead Tank

Figure 44: A SCADA layout

The SCADA dashboard will visualize:

- Live flow rates and water levels in tanks
- Pressure readings at nodal points
- Leak notifications and irregular usage trends
- Turbidity and chlorine levels at treatment and outflow points

This technology will enable for predictive maintenance, faster repair response, and optimal zone-based distribution planning.

8.4.3 Institutional Setup and Capacity Building

A specialized Smart Water Division within PHED should be created to manage the deployment and operation of the smart metering and SCADA program. This group will collaborate with vendors, monitor installations, maintain consumer data privacy, and build analytics tools. Capacity-building initiatives will be necessary to teach municipal engineers and operators in SCADA usage, data interpretation, and customer engagement.

Additionally, a consumer grievance redressal process should be set up to assist users with meter disputes, billing questions, and system complaints.

CHAPTER 9 – CONCLUSION

The present study looked into the water supply scenario in Kohima, Nagaland, and attempted to know about the prevailing issues and potential solutions. Even if Kohima experiences high rainfall annually, the city is still suffering from a critical shortage of water. Most of the regions, particularly in the northern and periphery parts, fail to receive regular piped water supply. Surveys indicated that water is supplied to most households for less than an hour and are largely dependent on water tankers, particularly during dry seasons. The study also determined that the city's water distribution system is old and in bad condition, with low storage capacity and no real-time monitoring.

To rectify the situation, a number of proposals were proposed. These are the replacement of aging pipes, designing the distribution system well, constructing additional service reservoirs, and identifying new sources such as the Zaru River. Rainwater harvesting was also given prime importance. The report revealed that Kohima has immense potential for harvesting and utilization of rainwater through rooftop systems, community tanks, and by connecting them to existing reservoirs. Another significant proposal is to implement smart water meters and SCADA systems for monitoring the supply, limiting wastage, and enhancing management.

But there are certain difficulties in putting forward these proposals. They are in terms of cost, which is too high; the absence of technical expertise; frequent maintenance requirements; and limited popular awareness. Furthermore, coordination and enforcement by the government will be required. Without public support and planning, the systems are unlikely to work optimally or last long.

Provided that these proposals are put in place carefully, they can alleviate most of Kohima's water issues. By conserving rainwater, enhancing supply systems, and employing technology to enhance water management, the city can minimize shortages and offer more stable service to its citizens. All these steps will ensure Kohima is ready for increased demand in the future as the population increases. In the long term, integrating infrastructure development with public engagement and intelligent policies can create a more equitable and sustainable water system for all.

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